LA-UR-22-20322

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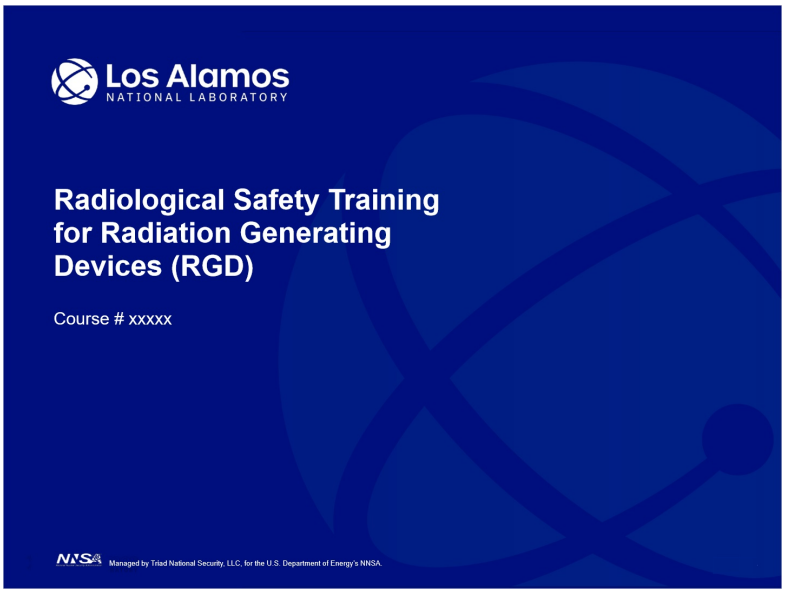
Title:	Radiation-Generating Device Safety Self-Study
Author(s):	Gillilan, Justin Parker
Intended for:	Online Training
Issued:	2022-01-13

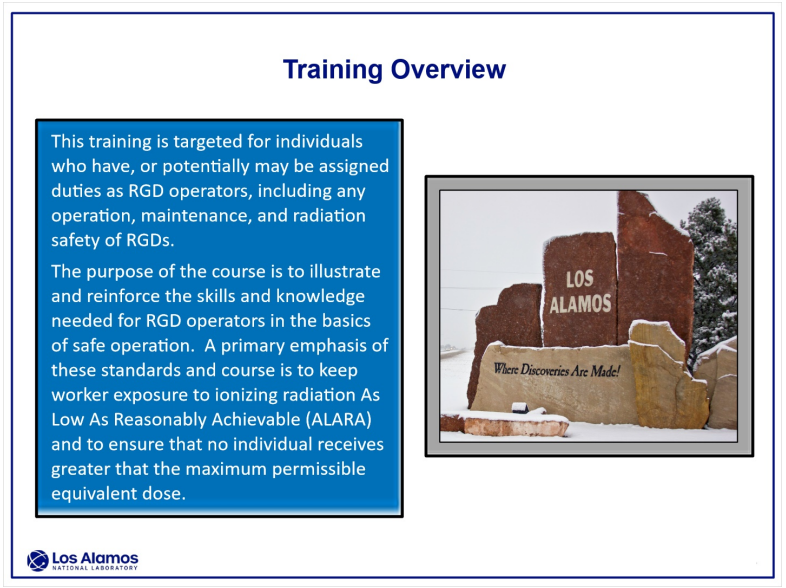
RGD Safety

1. RGD Safety Course Presentation

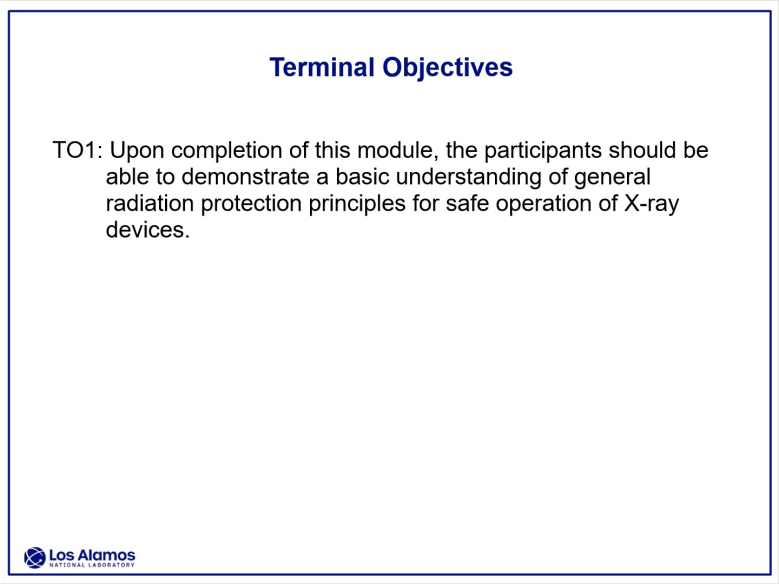
1.1 Radiological Safety Training for Radiation-Generating Devices



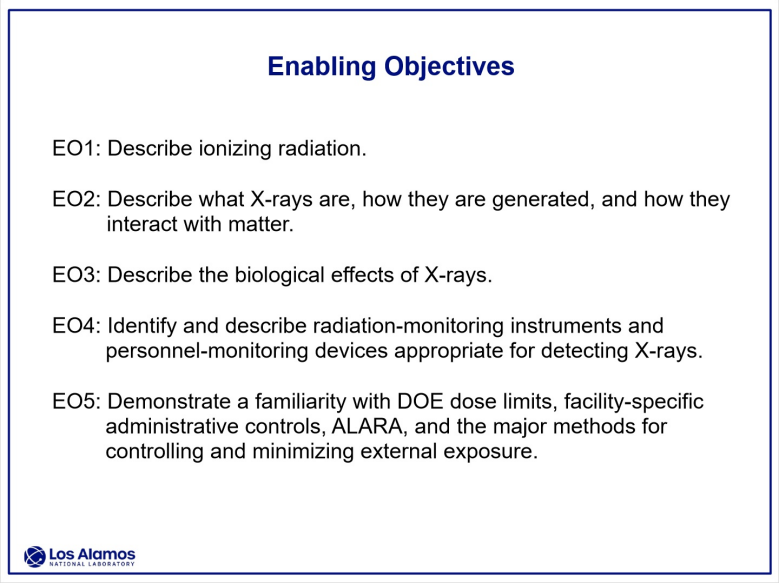
1.2 Training Overview



1.3 Terminal Objectives

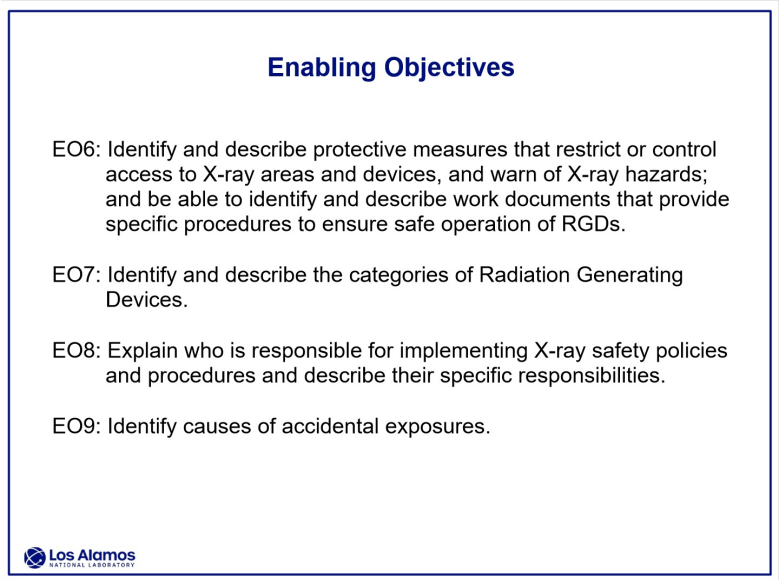


1.4 Enabling Objectives

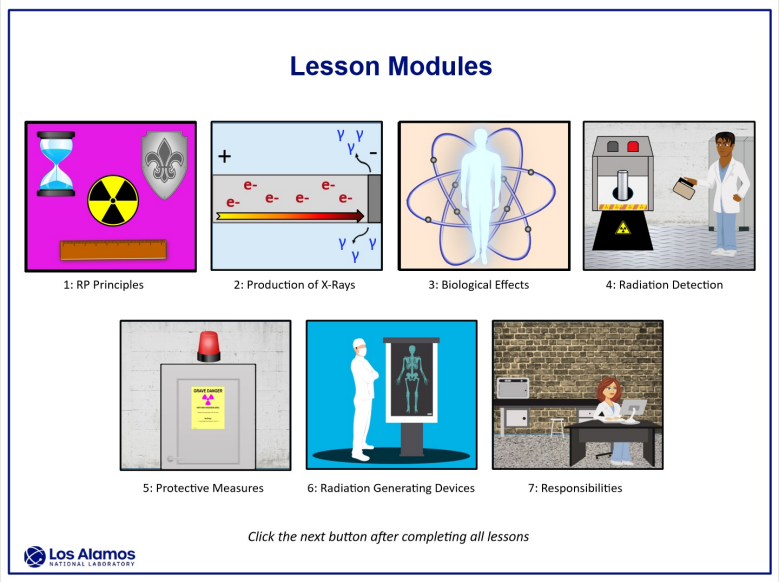


Notes:

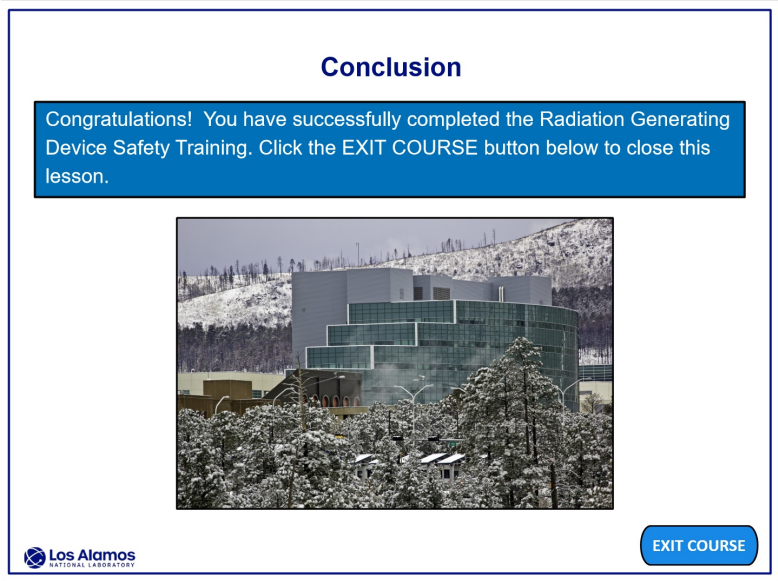
1.5 Enabling Objectives



1.6 Lesson Modules

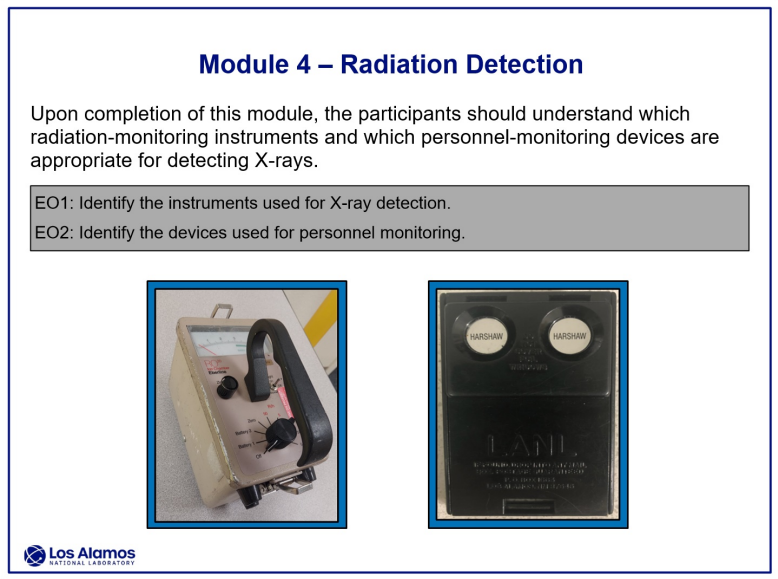


1.7 Conclusion

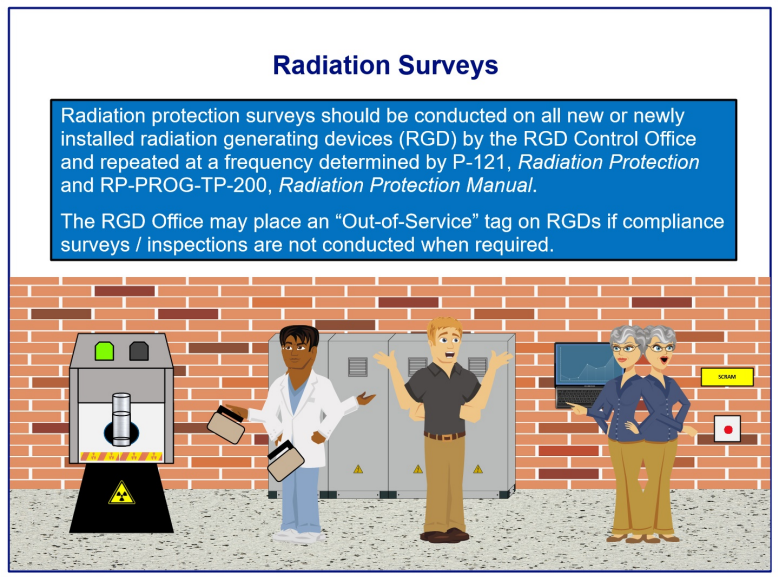


2. Module 4 - Radiation Detection

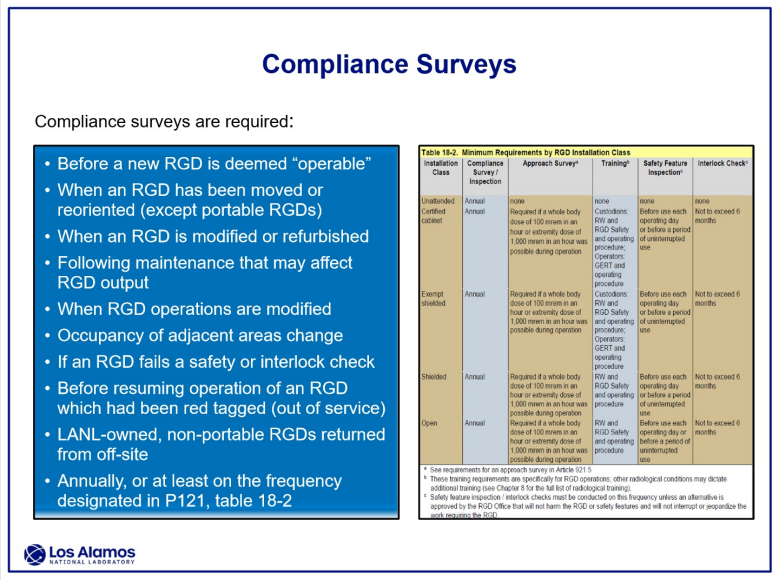
2.1 Module 4 Objectives



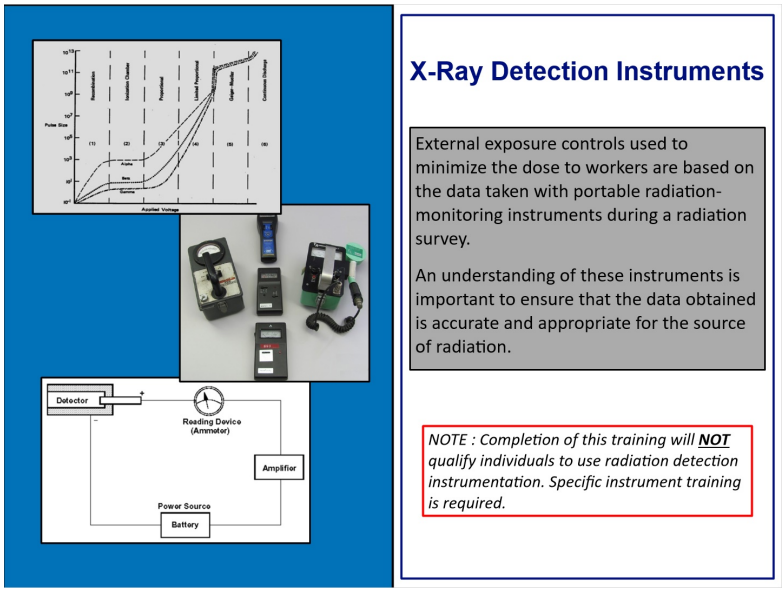
2.2 Performing Radiation Surveys



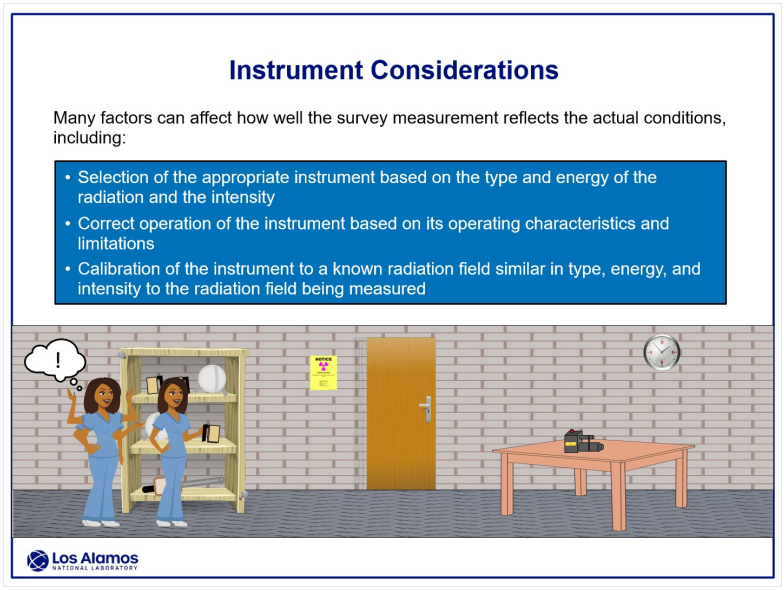
2.3 Compliance Surveys



2.4 X-Ray Detection Instruments



2.5 Instrument Considerations



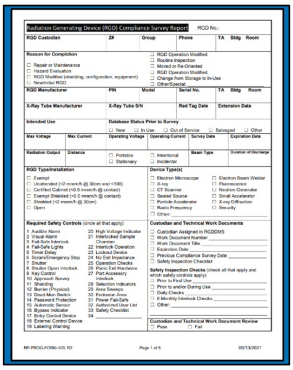
2.6 Performing the Survey

Performing the Survey

RGD operators, working under a Radiological Surveillance Authorization Agreement (RSAA) often use a radiation monitoring instrument for the ***detection*** of x-rays.

During an approach survey, an RGD operator may use an ion chamber to verify that the device is off before entry into the area.

The ***measurement*** of x-rays is normally the job of a qualified radiological control technician (RCT) from the RGD Control Office.



RP-PROG-FORM-103, *Radiation Generating Device (RGD) Compliance Survey Report*

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2.7 Instrument Classifications

Instrument Classifications

Instruments such as Geiger-Mueller (GM) counters, which count individual photons in counts per minute (cpm), are sensitive to X-rays. However, because a low-energy and a high-energy photon are each assigned one count, the GM counters tend to over respond to the low-energy photons.

Measurement of radiation dose rates and surveys of record require an instrument that reads in roentgen or rem per hour (R/hour, mR/hour, rem/hour, mrem/hour). Ion chambers, which detect current instead of counting pulses, have the flattest energy response.

Other specialized monitoring instruments are often used by the RGD Control Office RCTs.

RO-20 (Ion Chamber)

Teletector (GM Detector)

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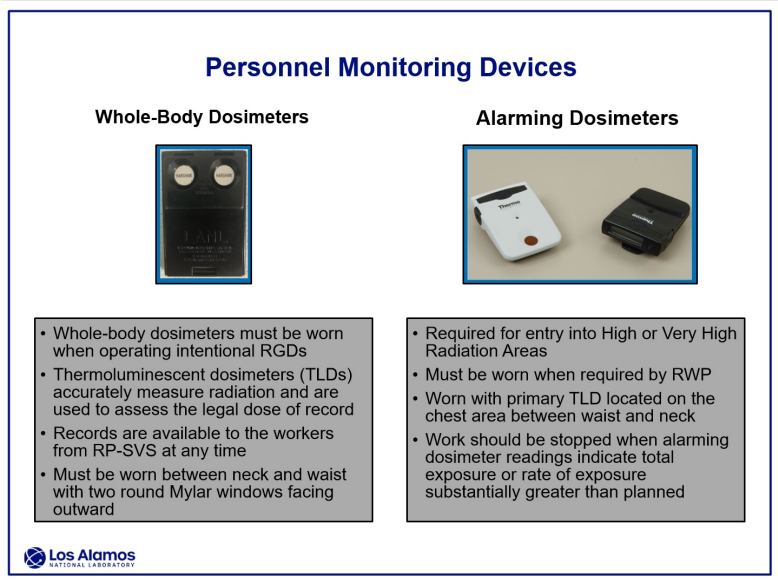
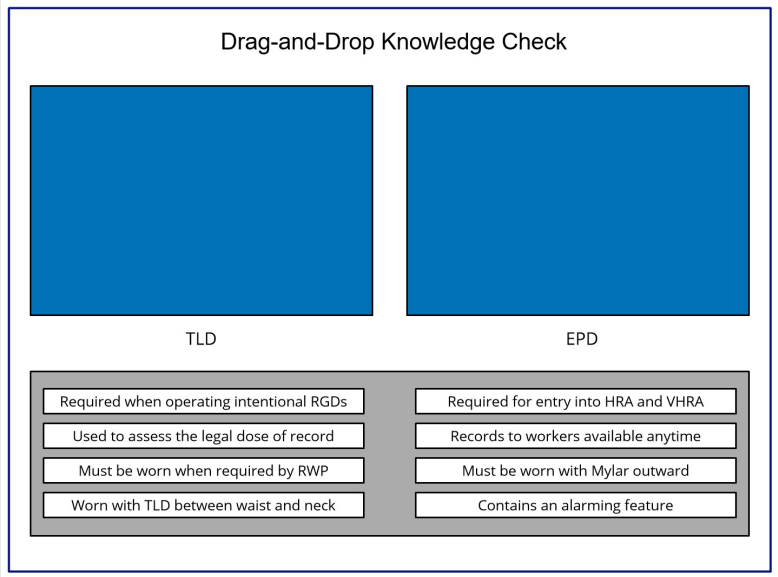
2.8 Personnel Monitoring Devices



2.9 Knowledge Check

(Drag and Drop, 10 points, 2 attempts permitted)



Drag Item	Drop Target
Used to assess the legal dose of record	Rectangle 2

Records to workers available anytime	Rectangle 2
Must be worn with Mylar outward	Rectangle 2
Required when operating intentional RGDs	Rectangle 2
Must be worn when required by RWP	Rectangle 3
Required for entry into HRA and VHRA	Rectangle 3
Contains an alarming feature	Rectangle 3
Worn with TLD between waist and neck	Rectangle 3

Drag and drop properties
Snap dropped items to drop target (Free)
Delay item drop states until interaction is submitted

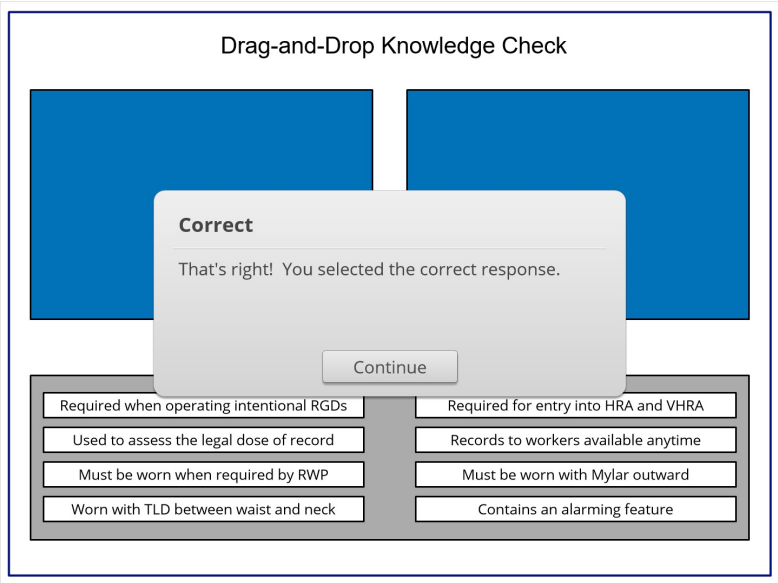
Feedback when correct:

That's right! You selected the correct response.

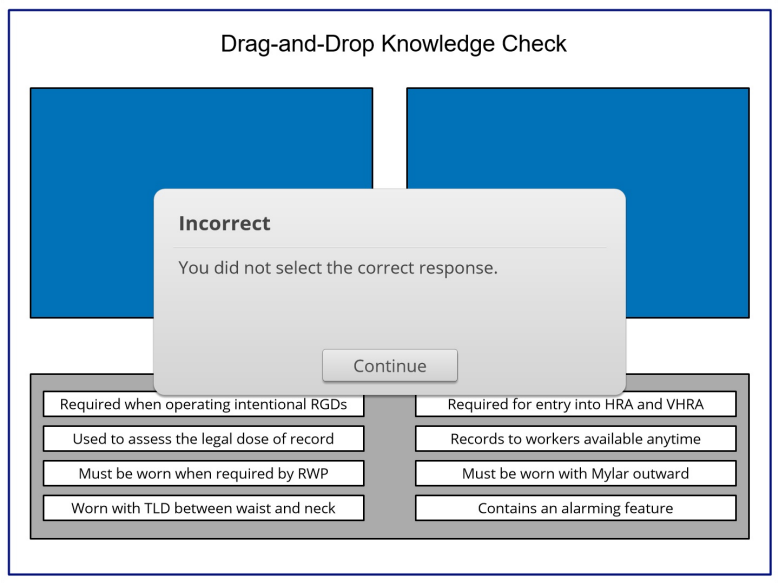
Feedback when incorrect:

You did not select the correct response.

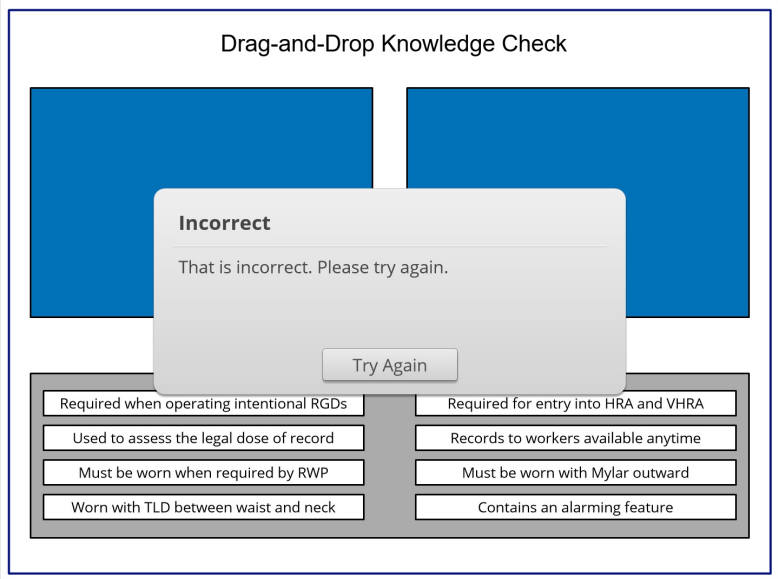
Correct (Slide Layer)



Incorrect (Slide Layer)

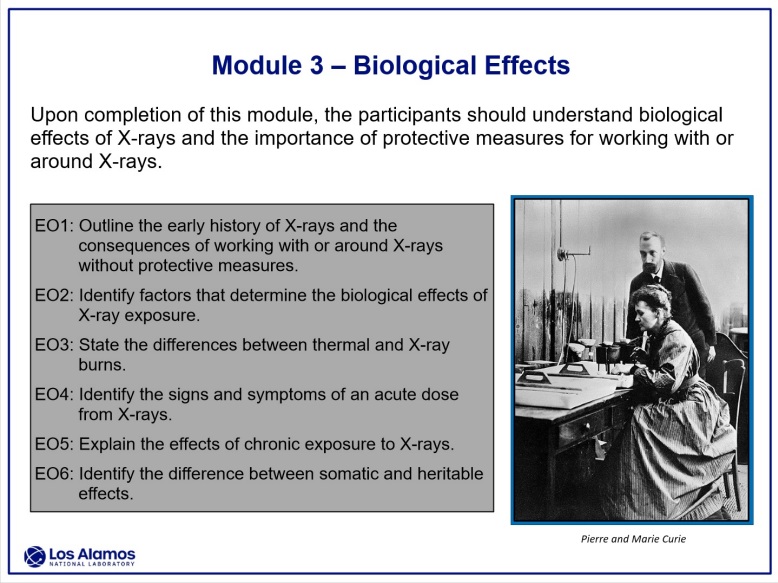


Try Again (Slide Layer)

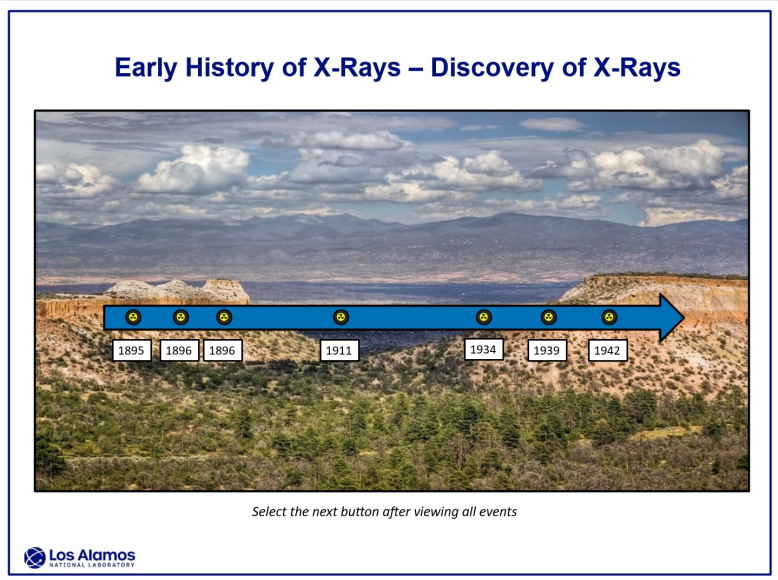


3. Module 3 - Biological Effects

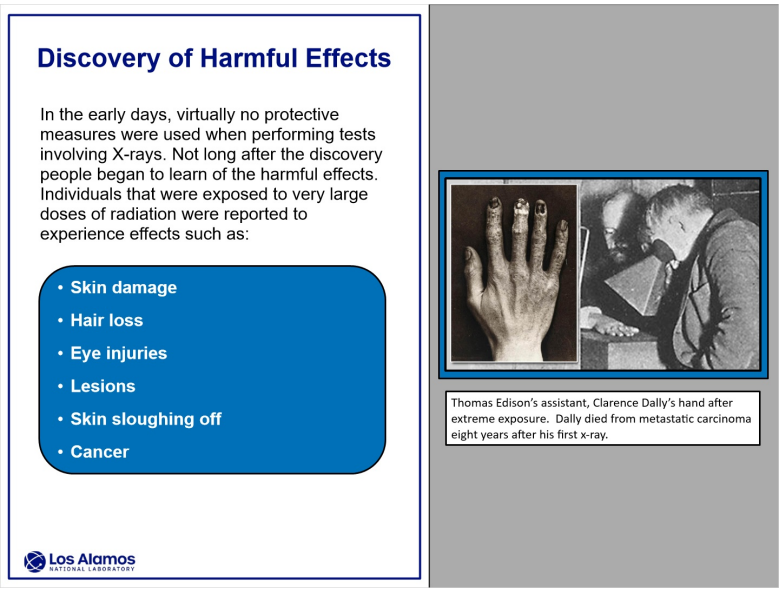
3.1 Module 3 Objectives



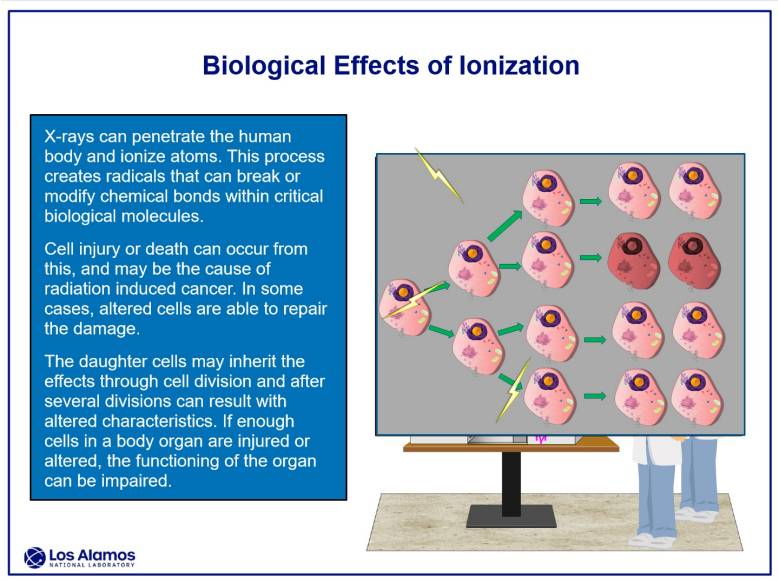
3.2 Discovery of X-rays



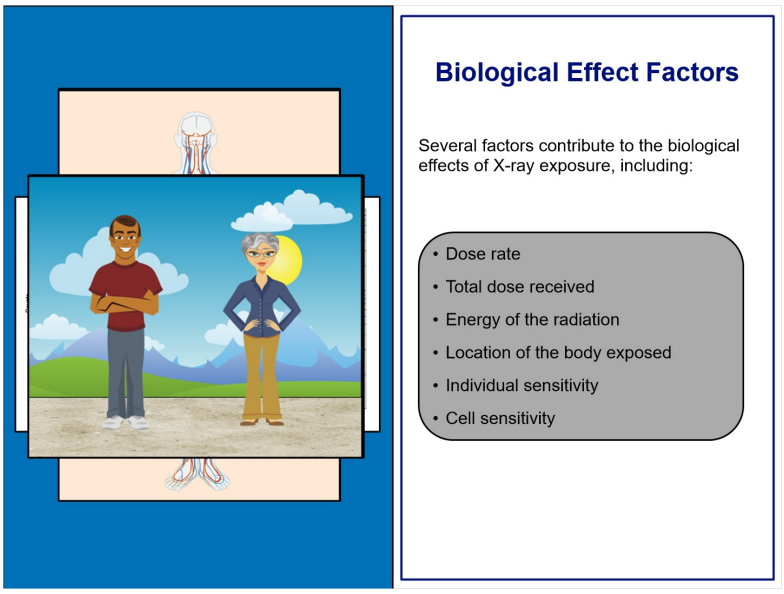
3.3 Discovery of Harmful Effects



3.4 Biological Effects



3.5 Biological Effect Factors



3.6 Dose Rate

Dose Rate

Acute dose: A large amount of radiation received in a short period (seconds to days).

Chronic dose: Smaller amounts of radiation taken in over a longer period of time (months to years).

For the same total amount of dose, an acute dose is more damaging than a chronic dose. It is believed that this effect is due to the ability of cells to repair damage over time. With an acute dose, a cell may receive many "hits" without sufficient time to repair the damage.

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3.7 Total Dose

Total Dose Received

Dose Recieved	Symptoms
< 25 Rem	• Generally not clinically observable
25 – < 100 Rem	• Generally no symptoms • May show mild prodromal effects (nausea and anorexia) • Possible bone marrow damage (decrease in red-white blood and platelet counts)
100 – 300 Rem	• May result in mild to severe nausea, malaise, anorexia, and infection • Hematologic damage is more severe

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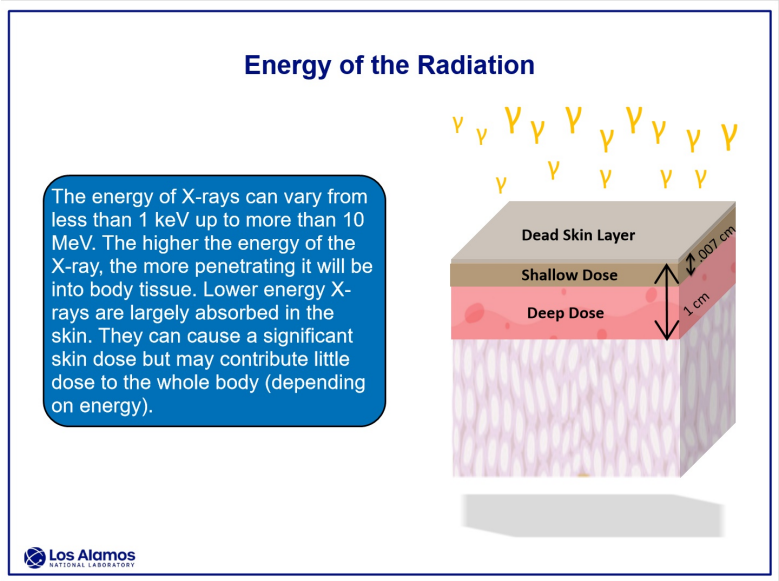
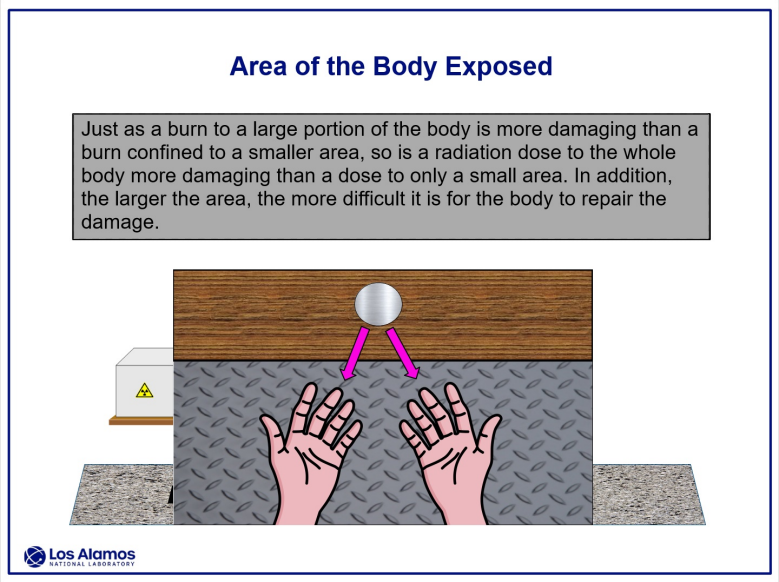
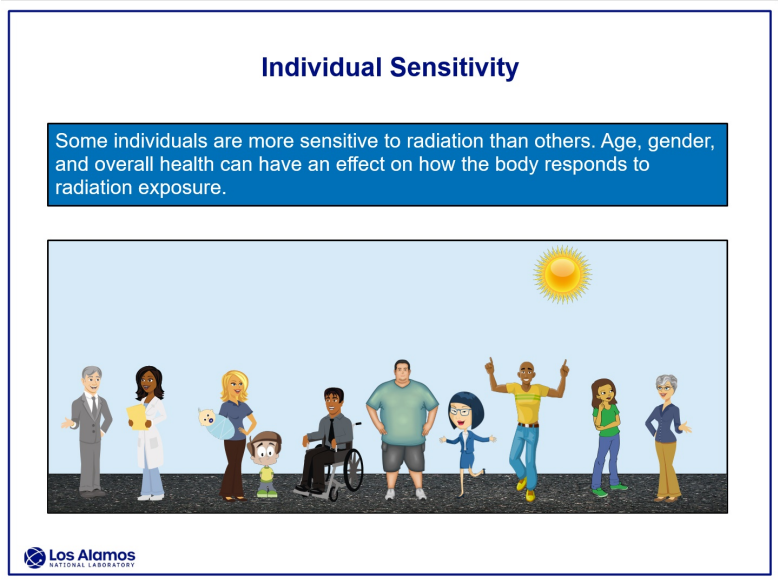
3.8 Energy of the Radiation



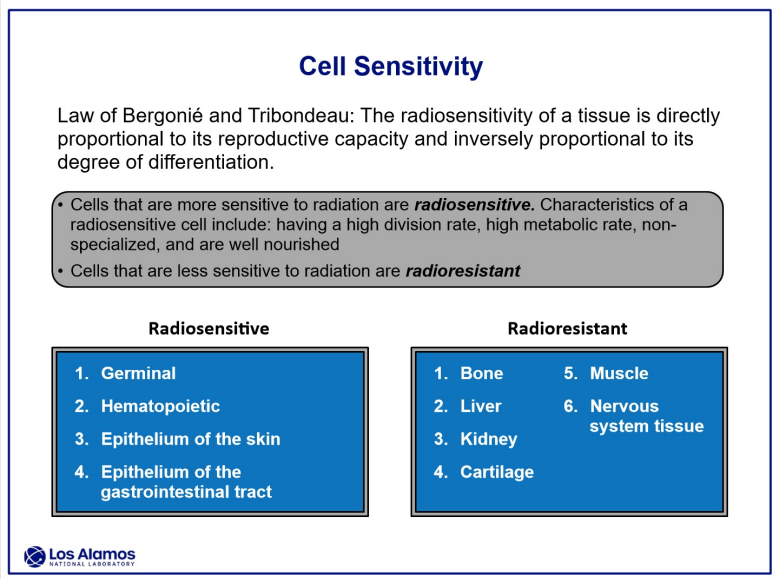
3.9 Area of the Body Exposed



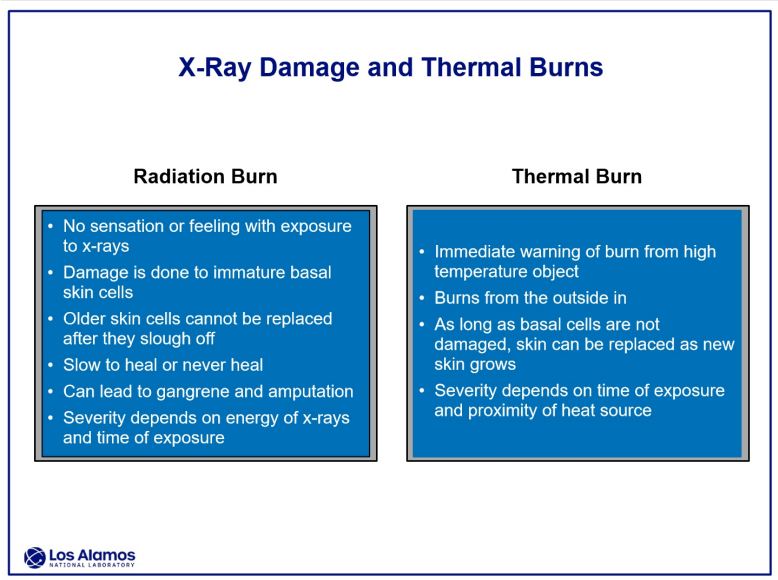
3.10 Individual Sensitivity



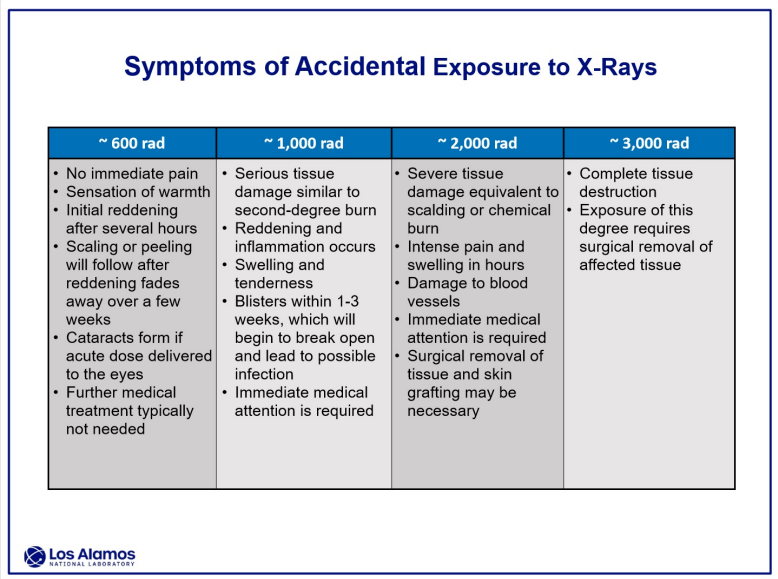
3.11 Cell Sensitivity



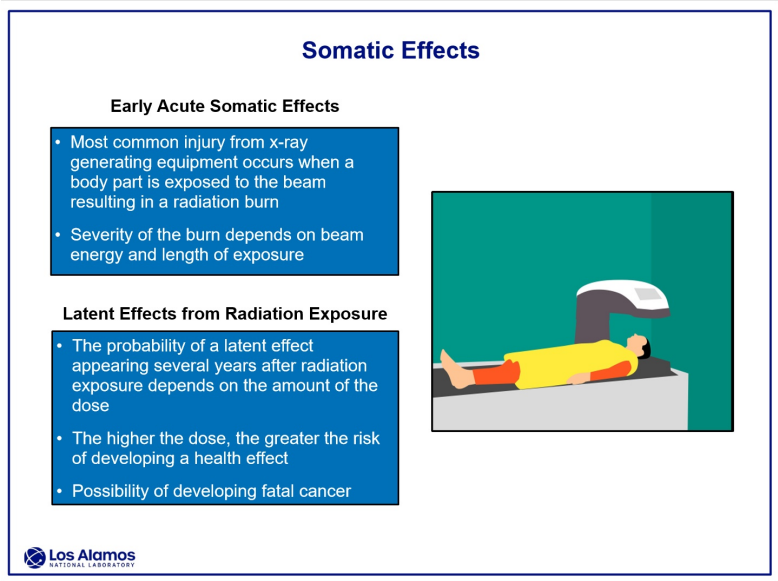
3.12 X-Ray Damage and Thermal Burns



3.13 Symptoms of Accidental Exposure

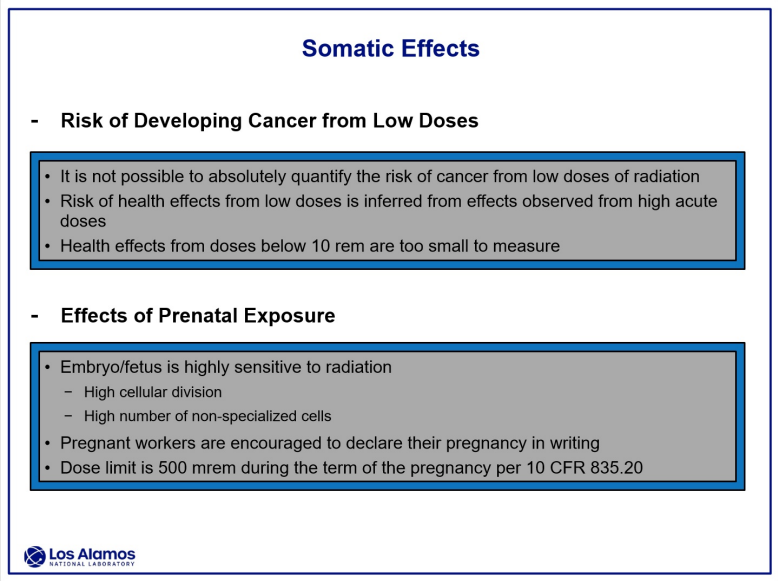


3.14 Somatic Effects



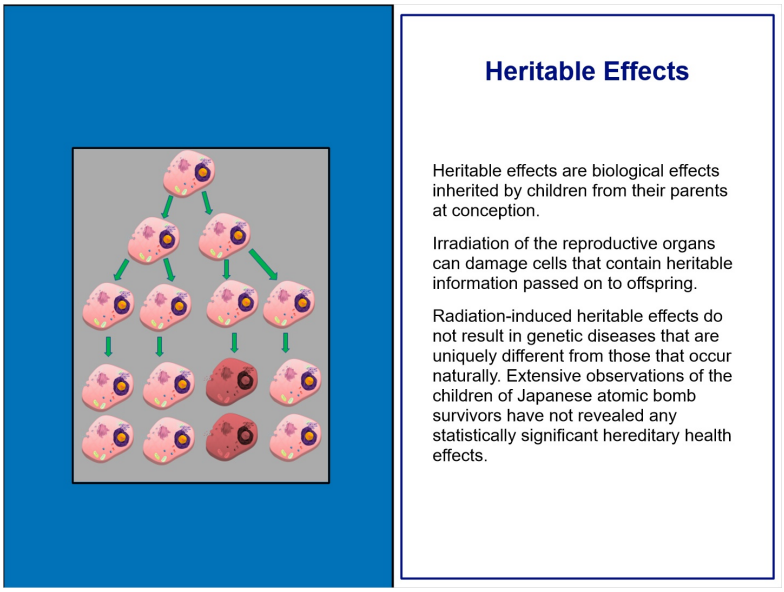
Notes:

3.15 Somatic Effects



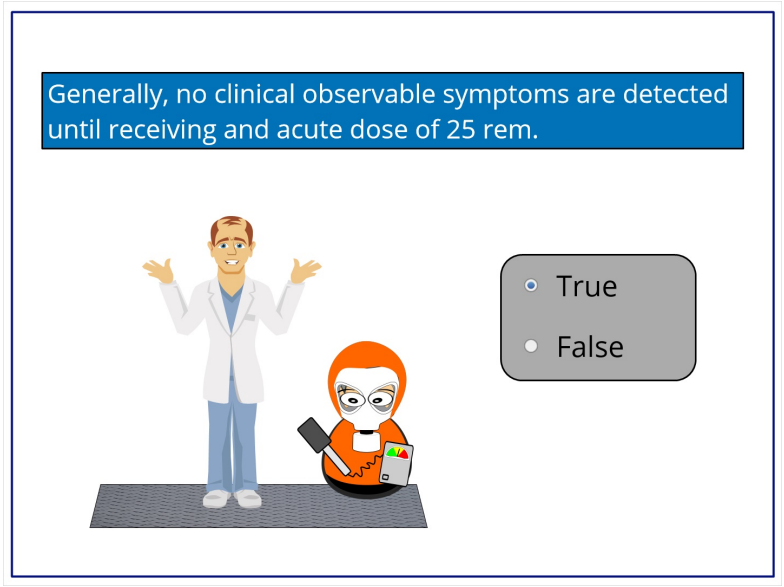
Notes:

3.16 Heritable Effects



3.17 Knowledge Check

(True/False, 10 points, unlimited attempts permitted)

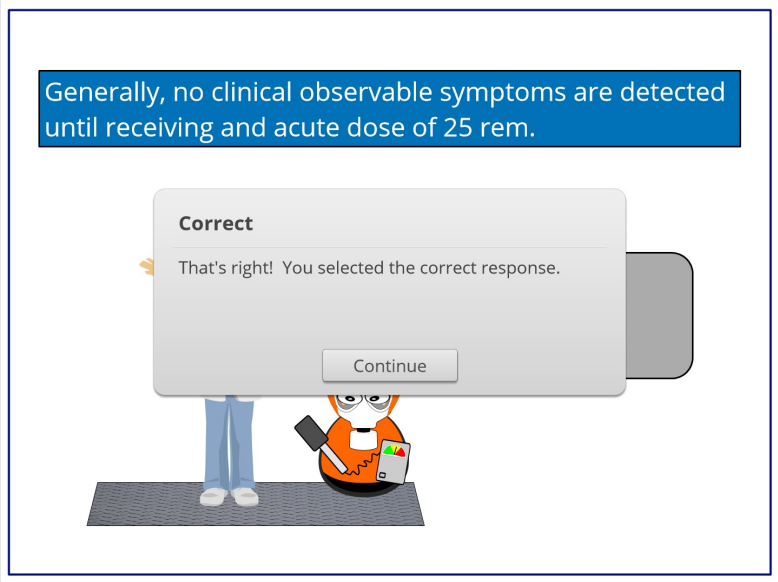


Correct	Choice
X	True
	False

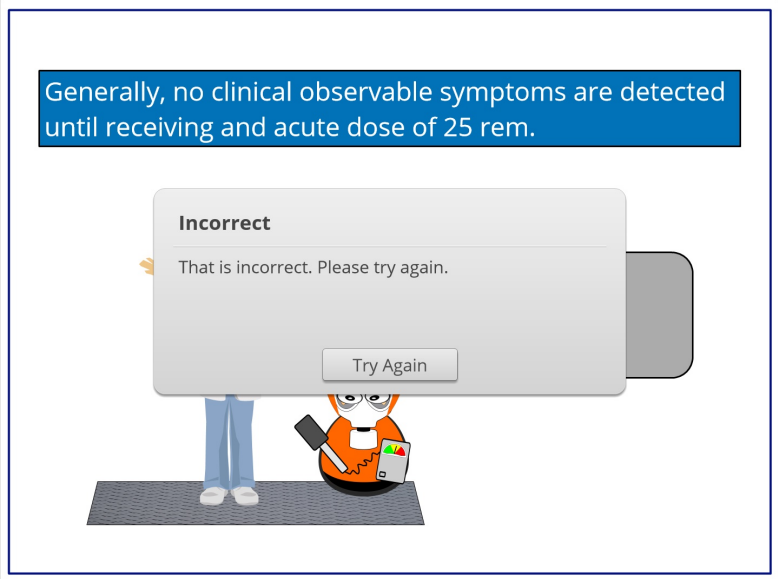
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

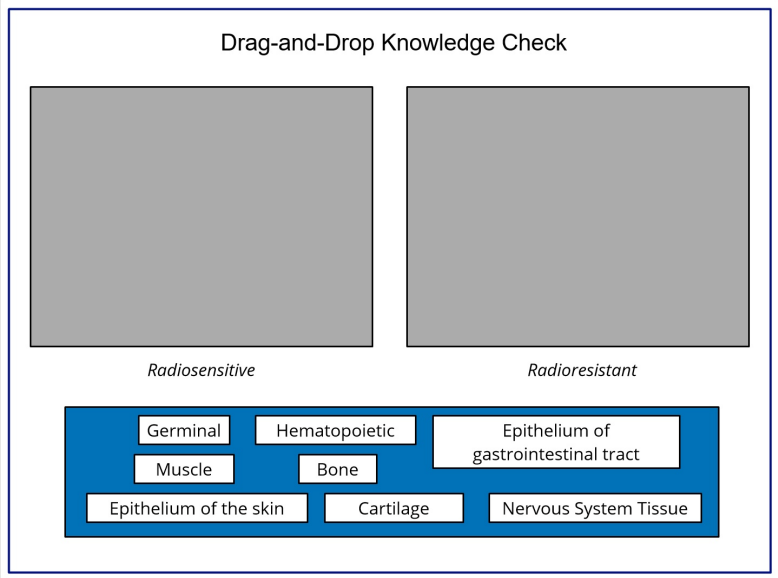


Try Again (Slide Layer)



3.18 Knowledge Check

(Drag and Drop, 10 points, 2 attempts permitted)



Drag Item	Drop Target
Germinal	Rectangle 2

Epithelium of the skin	Rectangle 2
Epithelium of gastrointestinal tract	Rectangle 2
Hematopoietic	Rectangle 2
Nervous System Tissue	Rectangle 3
Cartilage	Rectangle 3
Bone	Rectangle 3
Muscle	Rectangle 3

Drag and drop properties
Snap dropped items to drop target (Free)
Delay item drop states until interaction is submitted

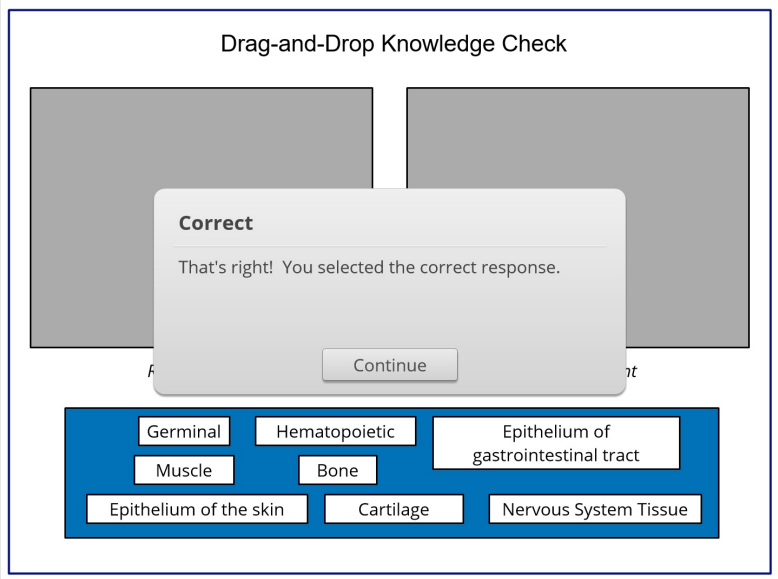
Feedback when correct:

That's right! You selected the correct response.

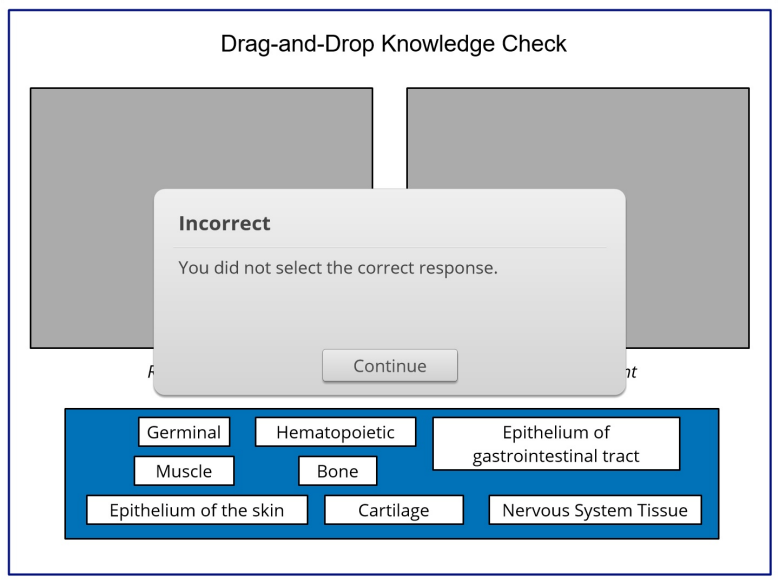
Feedback when incorrect:

You did not select the correct response.

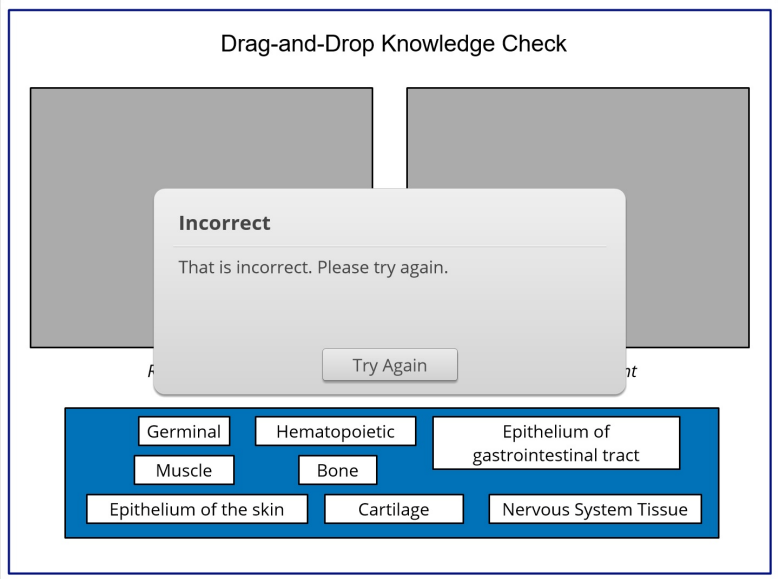
Correct (Slide Layer)



Incorrect (Slide Layer)

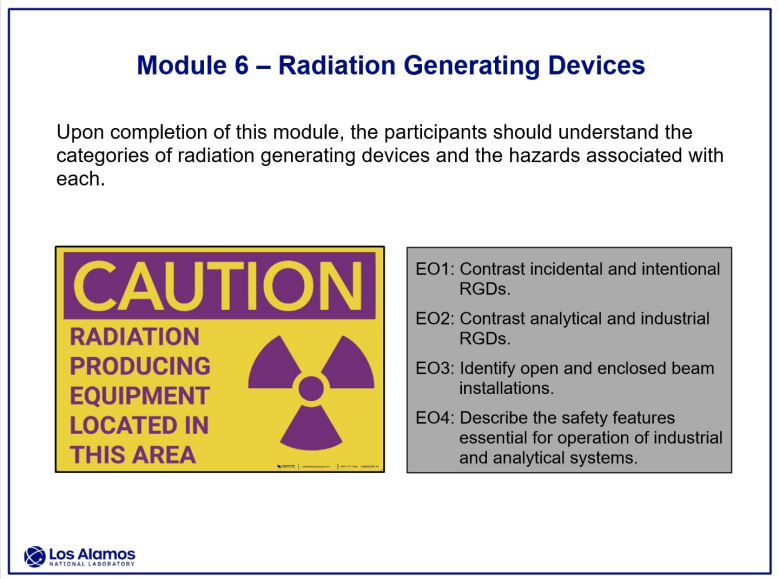


Try Again (Slide Layer)

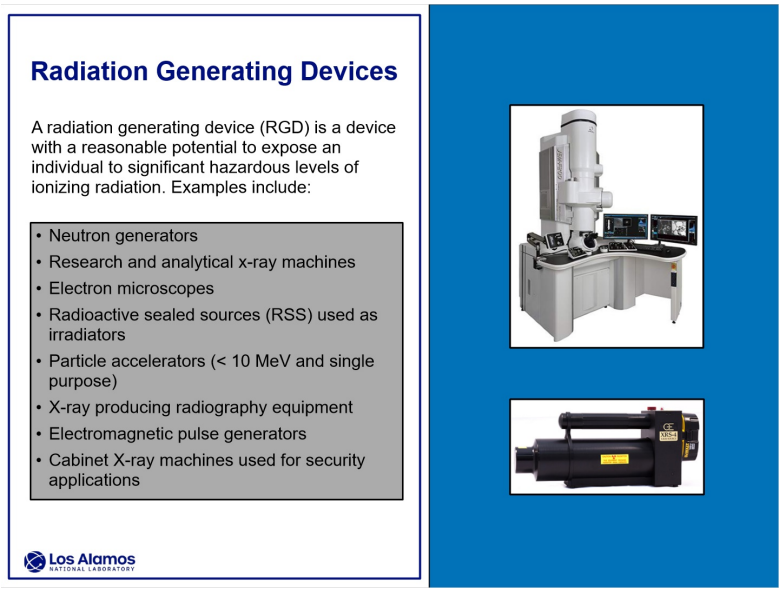


4. Module 6 - RGDs

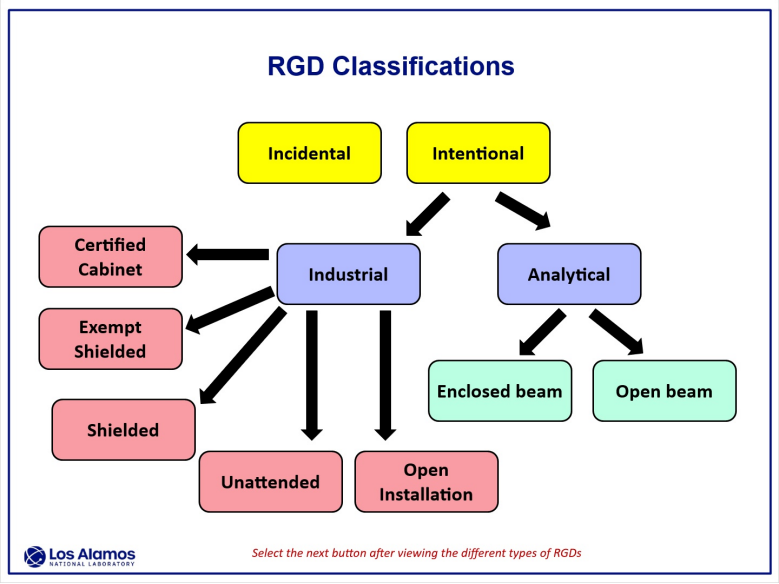
4.1 Module 6 Objectives



4.2 RGD Overview



4.3 RGD Classifications

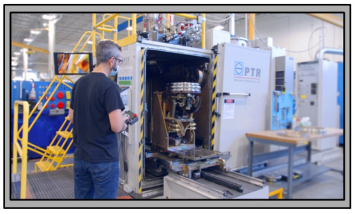


4.4 Incidental RGDs

Incidental

Incidental RGD – Produces X-rays that are not wanted or used as a part of the designed purpose of the machine. Shielding of an incidental X-ray device should preclude significant exposure.

- Computer monitors
- Televisions
- Electron microscopes
- High-voltage electron guns
- Electron beam welders
- Electrostatic separators



Any device that combines high voltage (> 40 kV), a vacuum, and a source of electrons could, in principle, produce X-rays.

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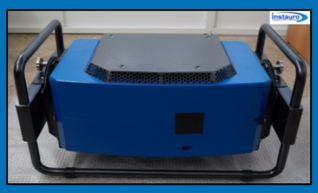
4.5 Intentional RGDs



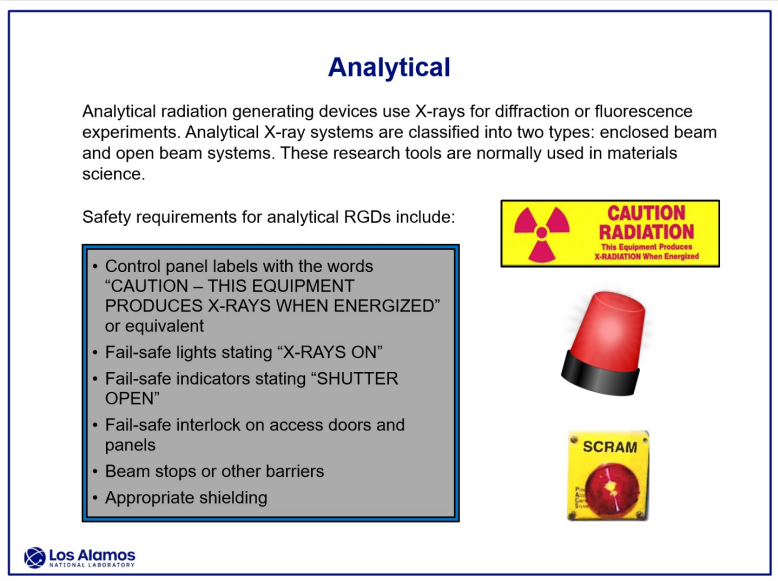
Intentional

Intentional RGDs generate an X-ray beam for a particular use.

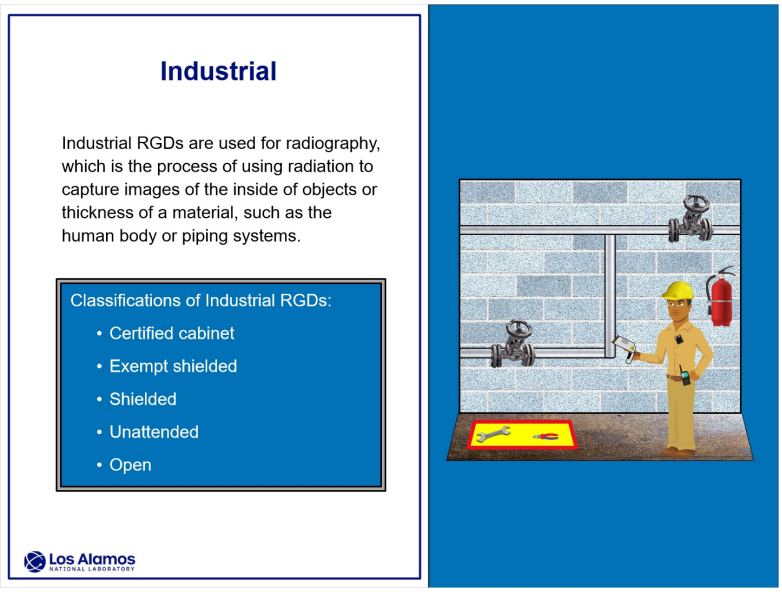
This type of RGD is divided into two different classifications, analytical and industrial. Intentional RGDs are typically housed within a fixed, interlocked, and/or shielded enclosure or room. Devices include:

- X-ray diffraction and fluorescence analysis systems
- Flash X-ray systems
- Medical X-ray machines
- Industrial cabinet and non-cabinet X-ray equipment
- Neutron generators

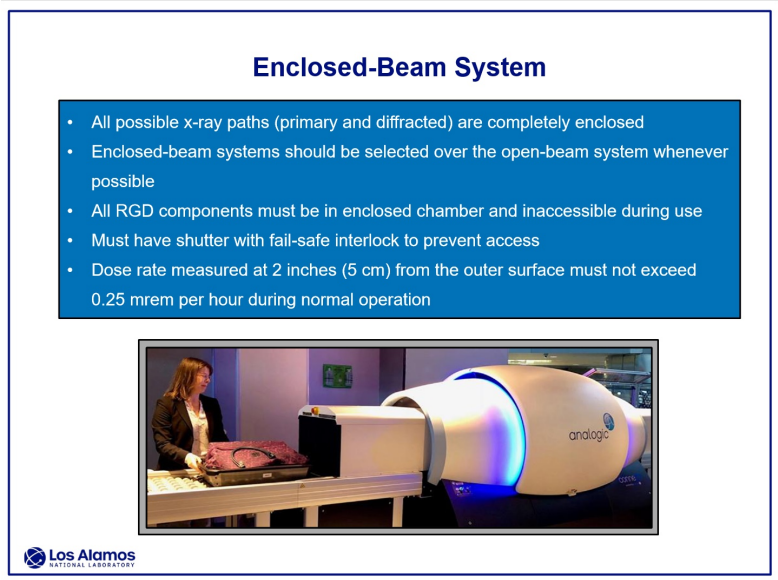
4.6 Analytical RGDs



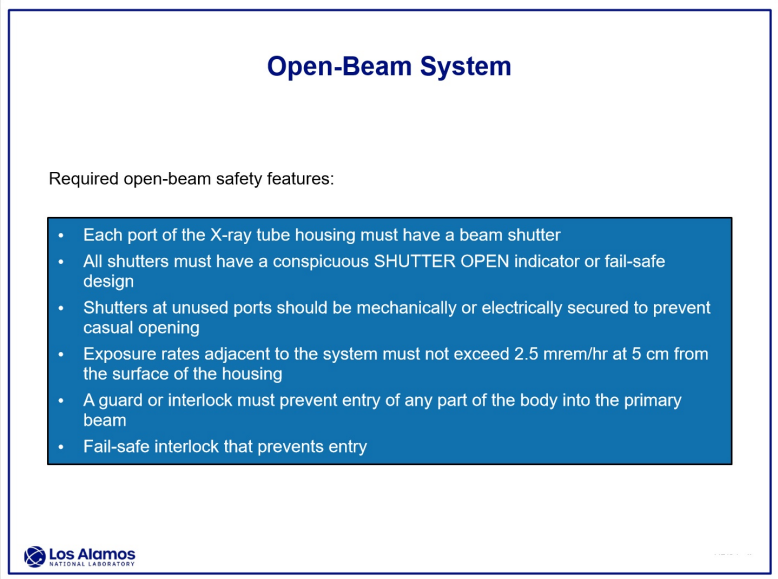
4.7 Industrial RGDs



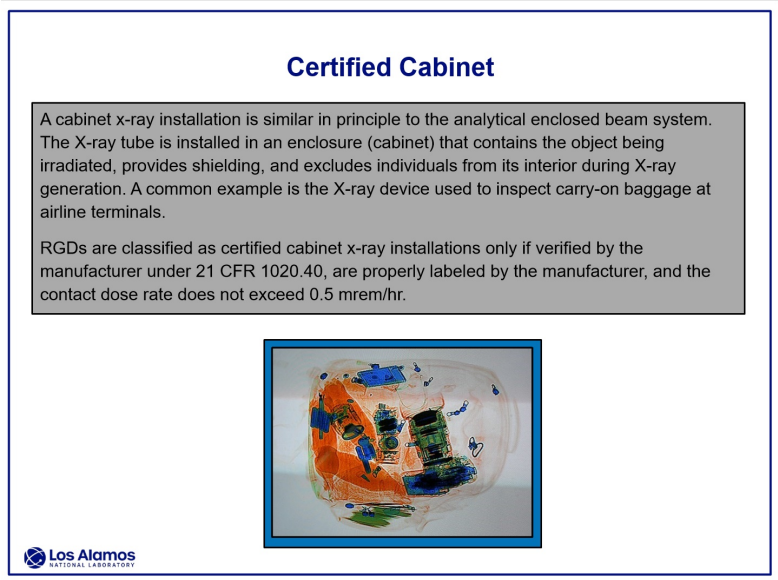
4.8 Enclosed Beam RGDs



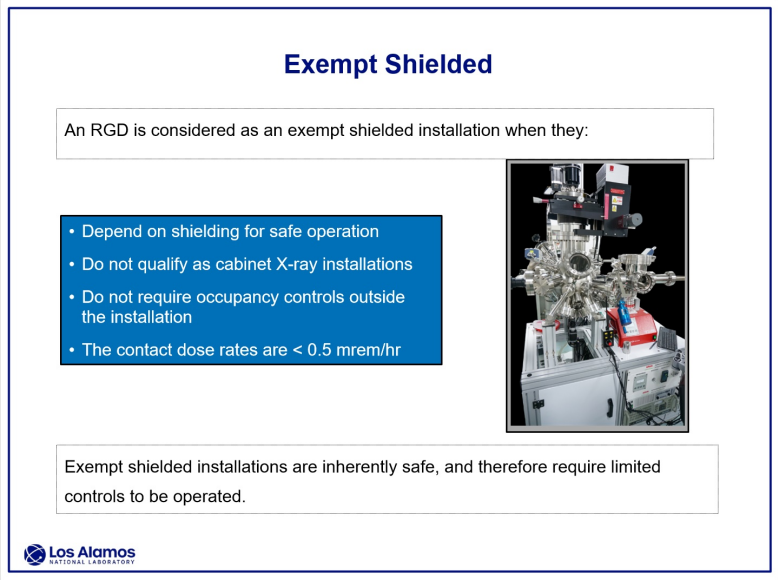
4.9 Open-beam System



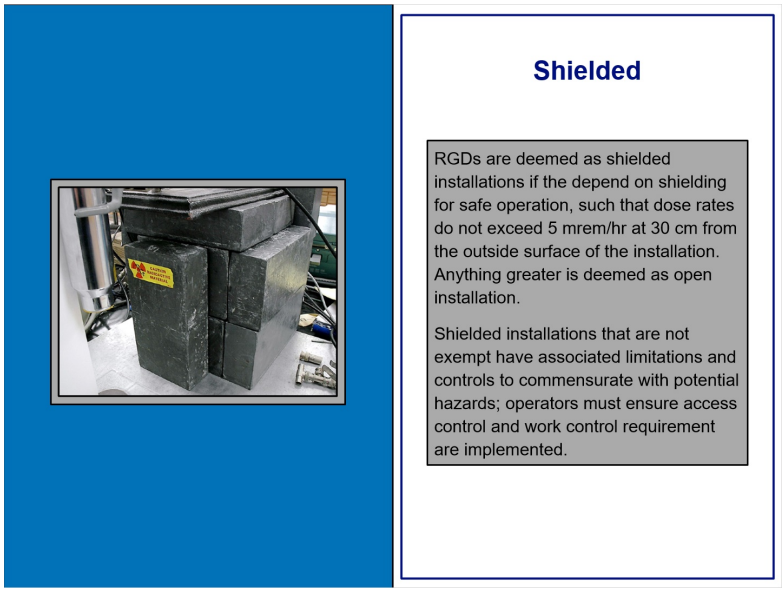
4.10 Certified Cabinet



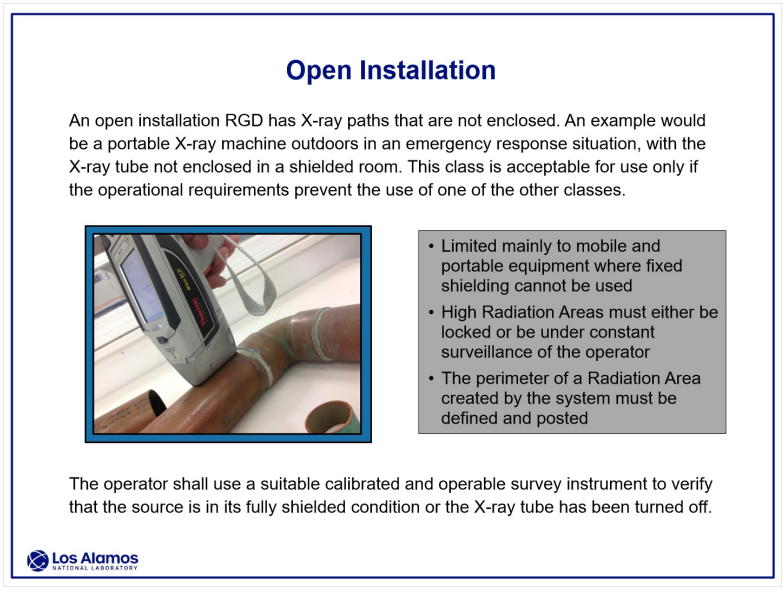
4.11 Exempt Shielded



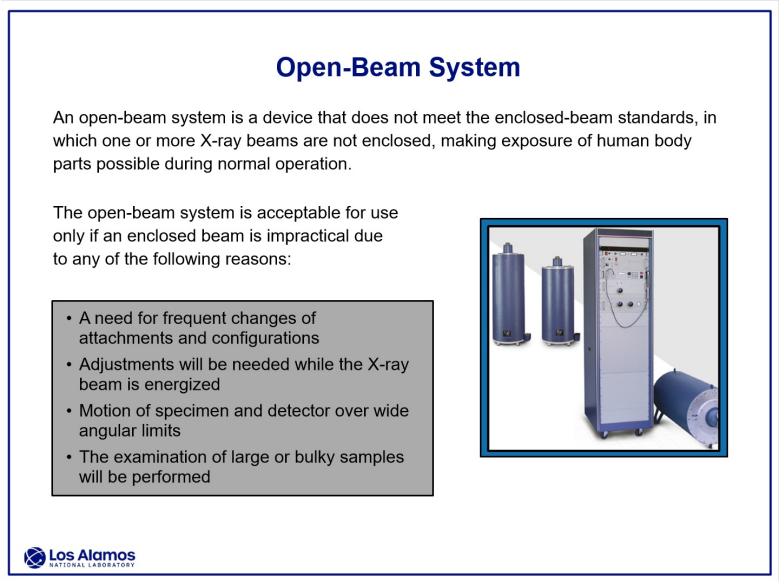
4.12 Shielded RGDs



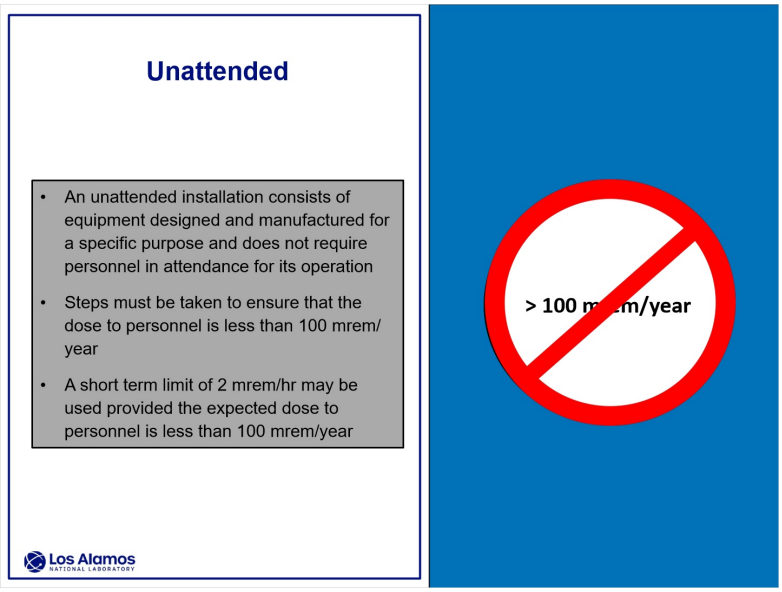
4.13 Open Installation



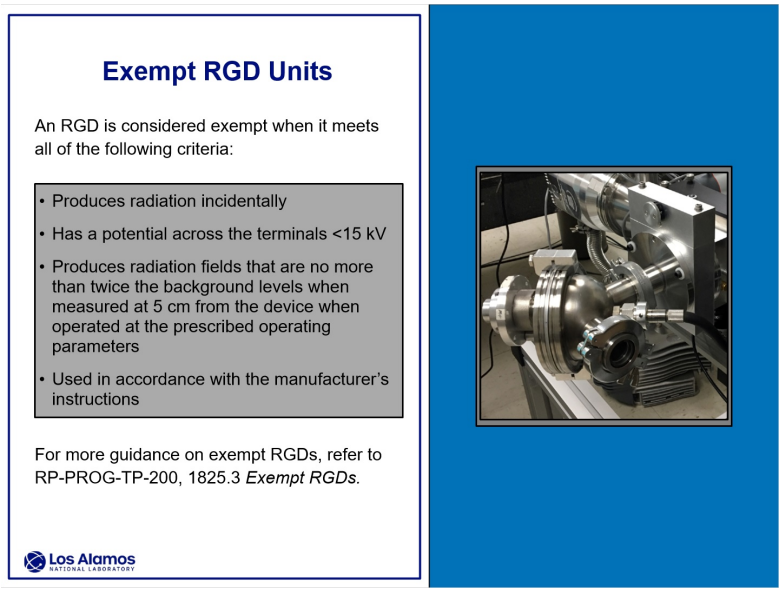
4.14 Open-beam System



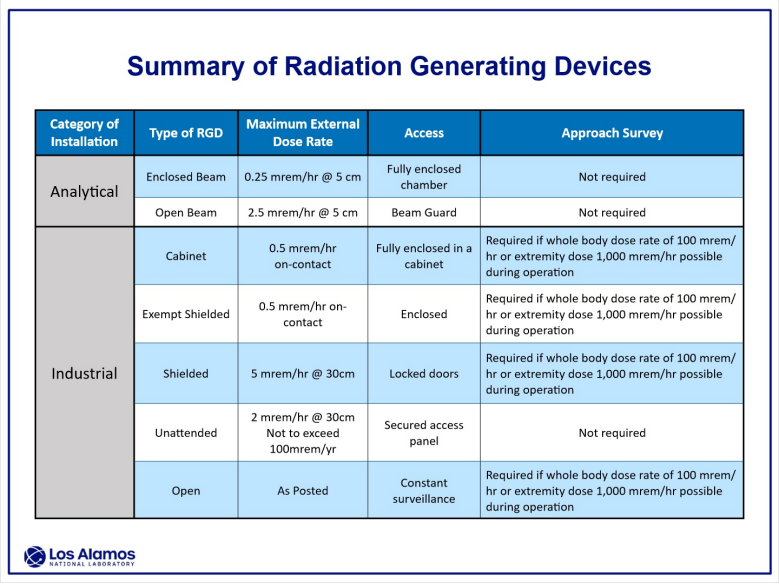
4.15 Unattended RGDs



4.16 Exempt RGD Units



4.17 Summary of Radiation Generating Devices



Summary of Radiation Generating Devices

Category of Installation	Type of RGD	Maximum External Dose Rate	Access	Approach Survey
Analytical	Enclosed Beam	0.25 mrem/hr @ 5 cm	Fully enclosed chamber	Not required
	Open Beam	2.5 mrem/hr @ 5 cm	Beam Guard	Not required
Industrial	Cabinet	0.5 mrem/hr on-contact	Fully enclosed in a cabinet	Required if whole body dose rate of 100 mrem/hr or extremity dose 1,000 mrem/hr possible during operation
	Exempt Shielded	0.5 mrem/hr on-contact	Enclosed	Required if whole body dose rate of 100 mrem/hr or extremity dose 1,000 mrem/hr possible during operation
	Shielded	5 mrem/hr @ 30cm	Locked doors	Required if whole body dose rate of 100 mrem/hr or extremity dose 1,000 mrem/hr possible during operation
	Unattended	2 mrem/hr @ 30cm Not to exceed 100mrem/yr	Secured access panel	Not required
	Open	As Posted	Constant surveillance	Required if whole body dose rate of 100 mrem/hr or extremity dose 1,000 mrem/hr possible during operation

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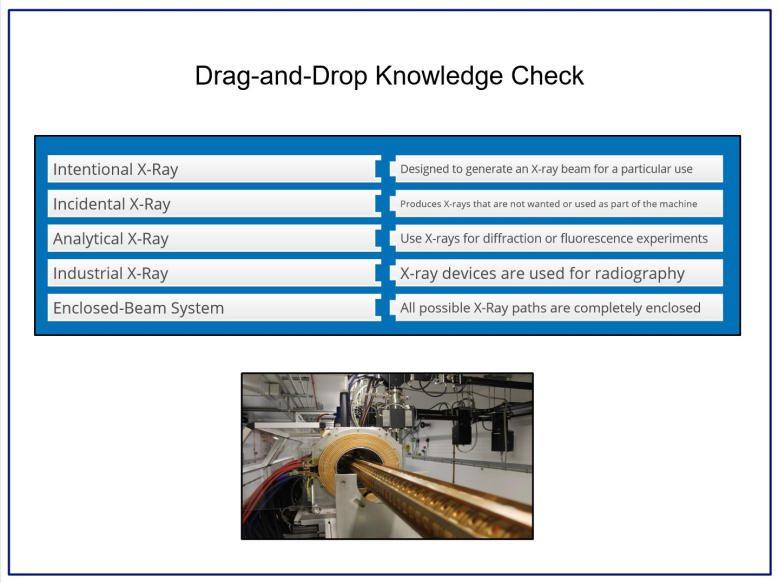
4.18 Knowledge Check

(Matching Drag-and-Drop, 10 points, unlimited attempts permitted)

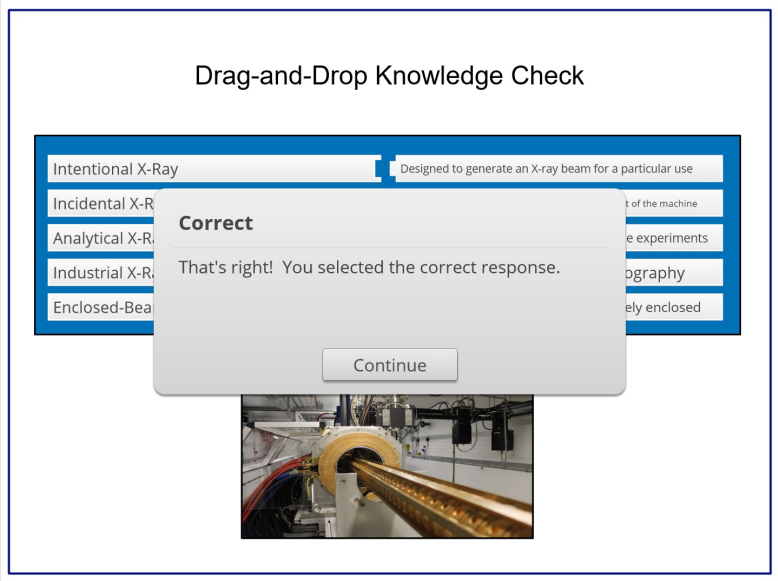


Correct	Choice
Intentional X-Ray	Designed to generate an X-ray beam for a particular use
Incidental X-Ray	Produces X-rays that are not wanted or used as part of the machine
Analytical X-Ray	Use X-rays for diffraction or fluorescence experiments
Industrial X-Ray	X-ray devices are used for radiography
Enclosed-Beam System	All possible X-Ray paths are completely enclosed

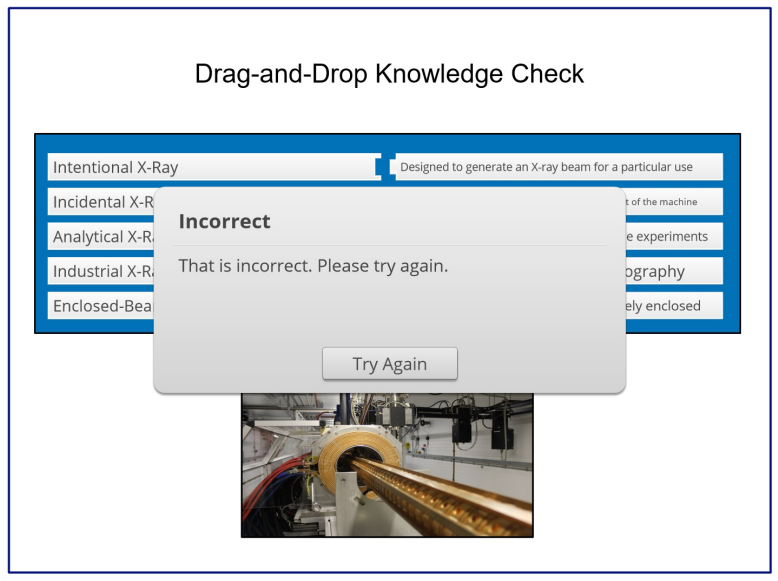
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)



Try Again (Slide Layer)

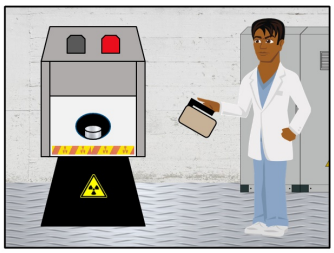


4.19 Knowledge Check

(Multiple Choice, 10 points, unlimited attempts permitted)

What must the operator use to verify the source of an Open Installation RGD is in its fully shielded condition?

- EPD alarm
- Calibrated and operable survey instrument
- Visual confirmation
- TLD
- No verification needed

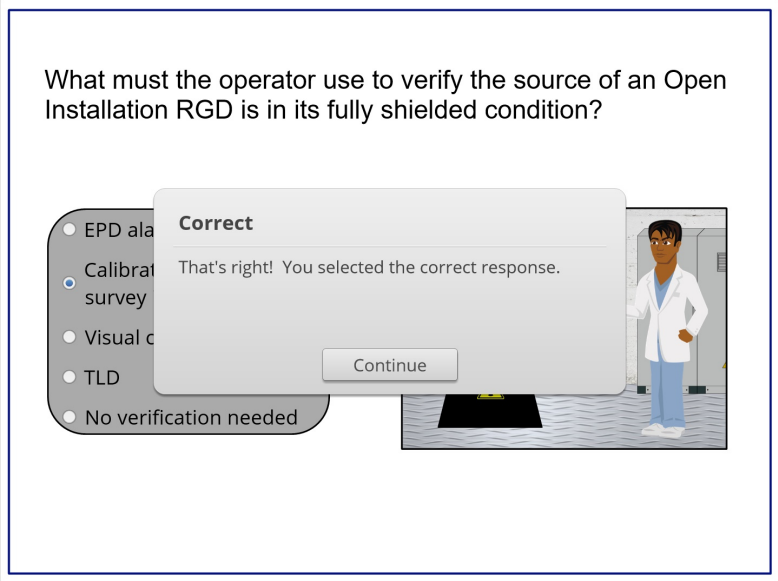


Correct	Choice
	EPD alarm
X	Calibrated and operable survey instrument
	Visual confirmation
	TLD
	No verification needed

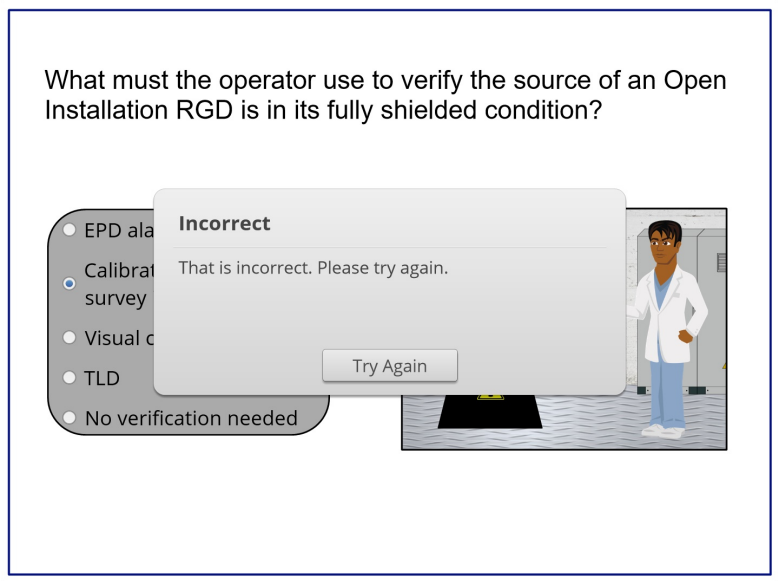
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

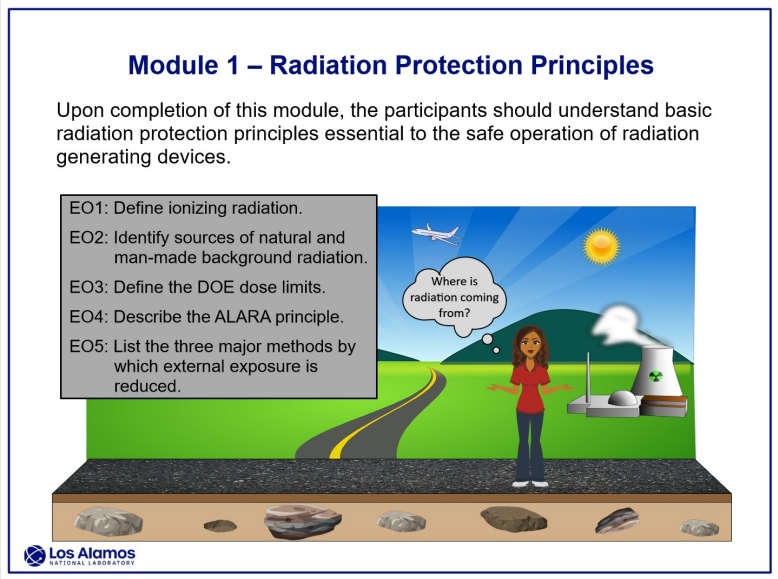


Try Again (Slide Layer)

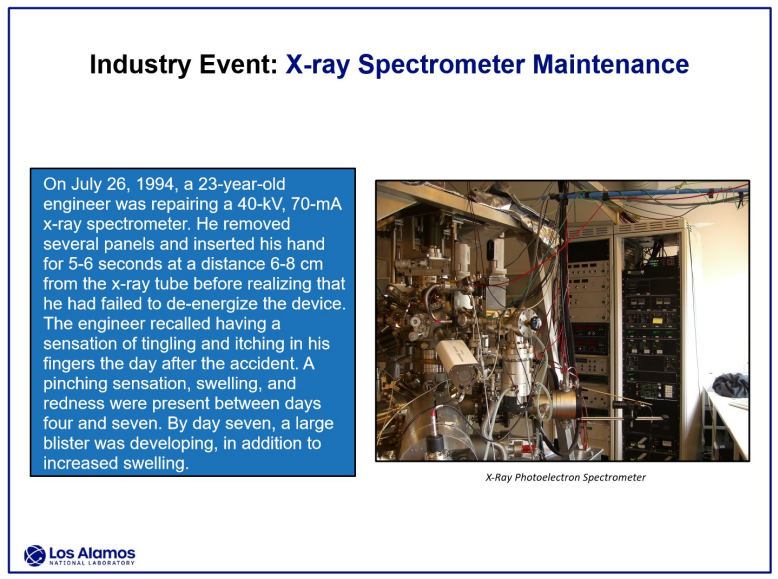


5. Module 1 - Radiation Protection Principles

5.1 Module 1 Objectives

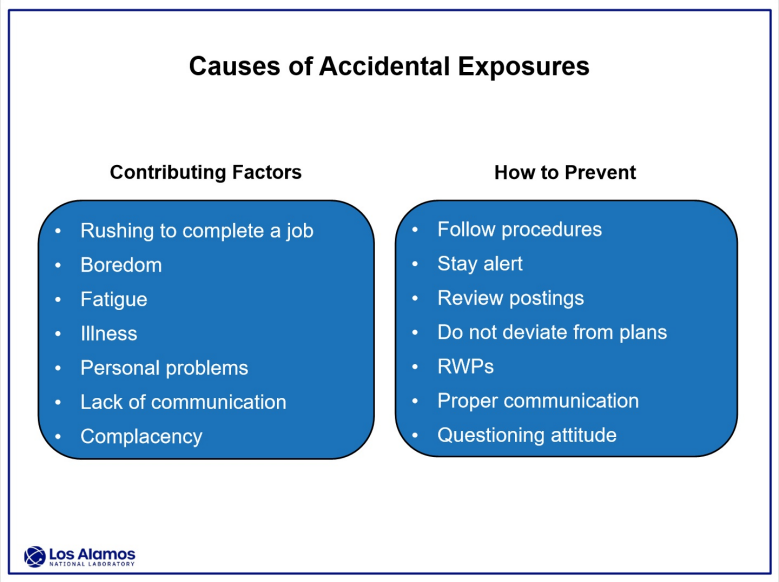


5.2 Industry Event

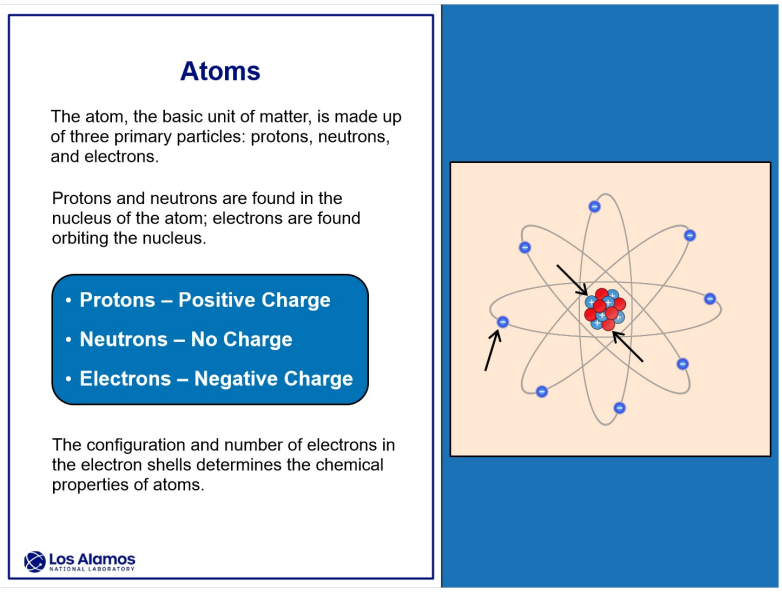


5.3 Industry Event

5.4 Causes of Accidental Exposures

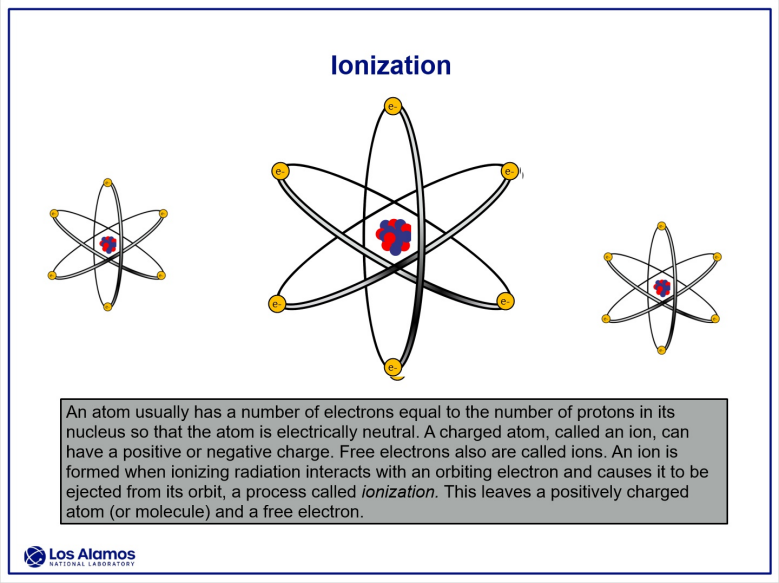


5.5 Atoms

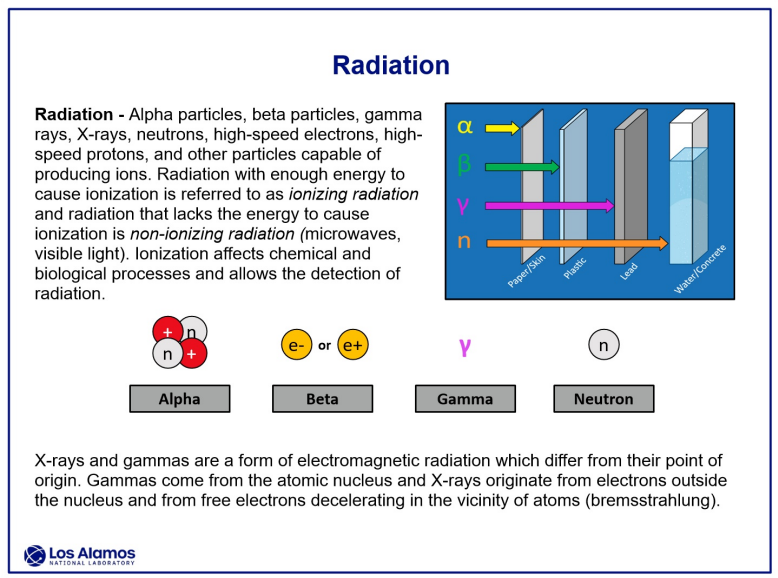


Notes:

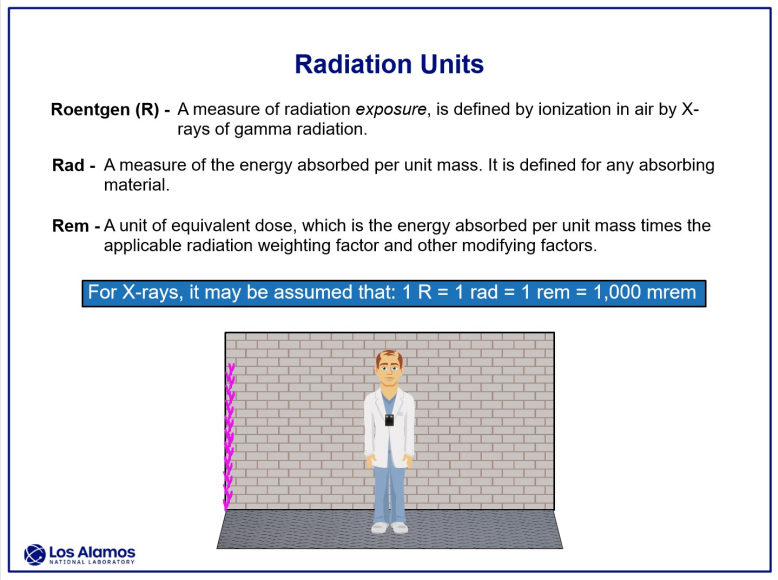
5.6 Ionization



5.7 Radiation

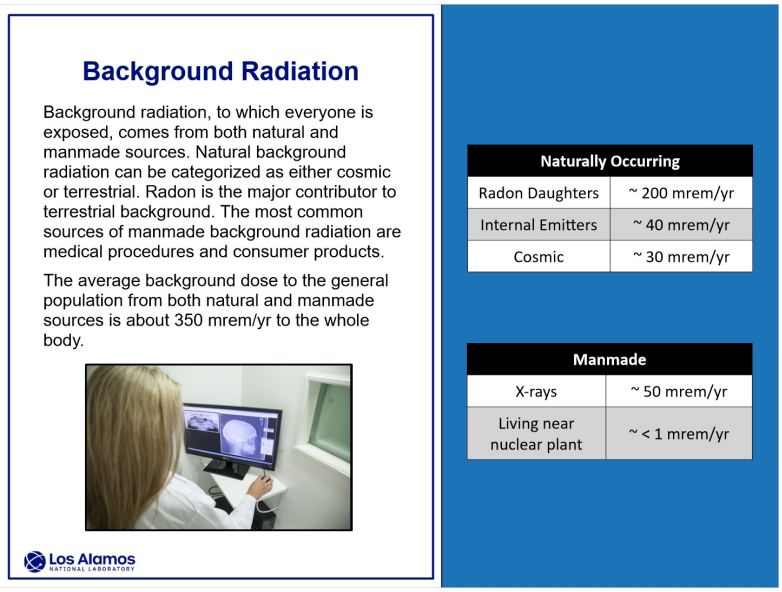


5.8 Radiation Units



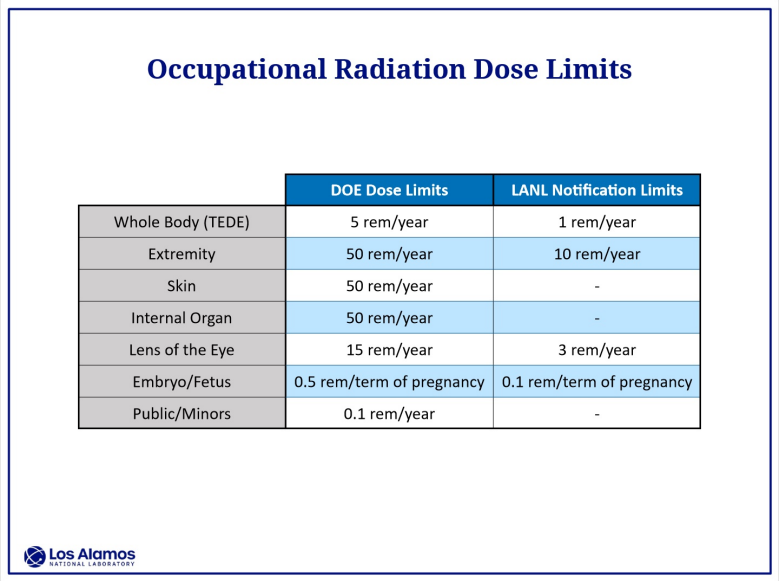
Notes:

5.9 Background Radiation



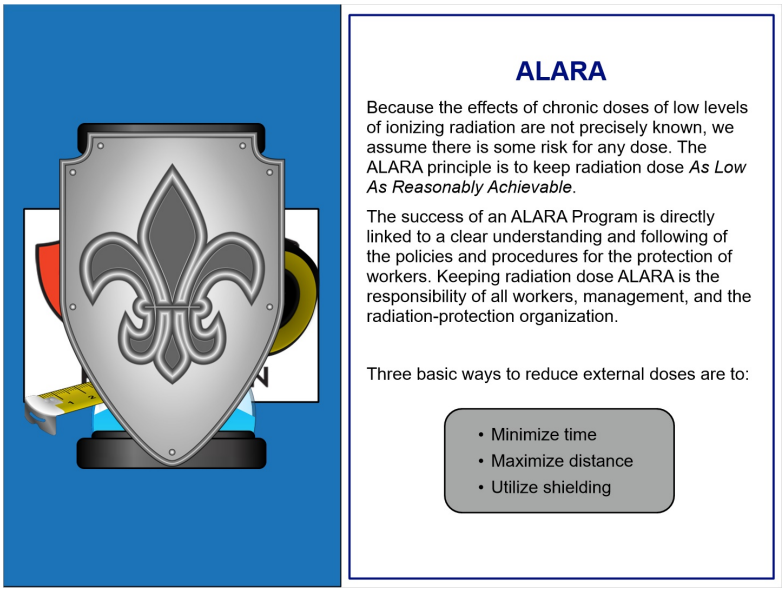
Notes:

5.10 Occupational Radiation Dose Limits



Notes:

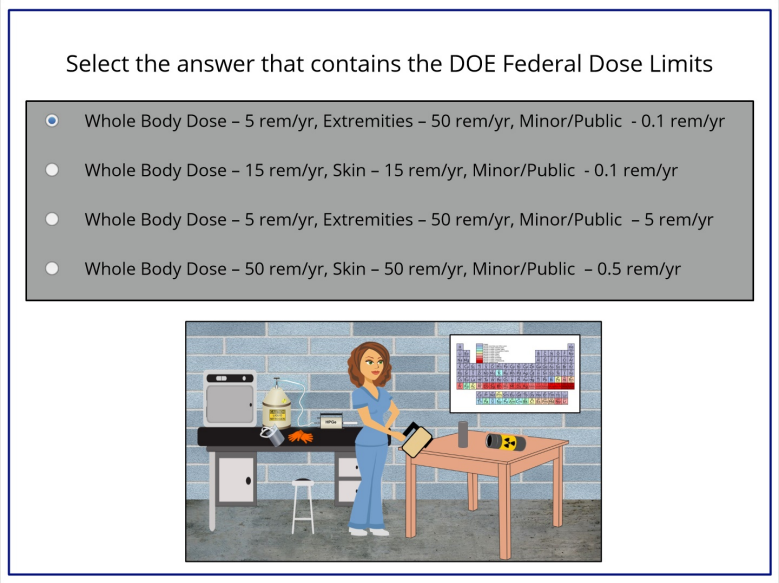
5.11 ALARA



Notes:

5.12 Knowledge Check

(Multiple Choice, 10 points, unlimited attempts permitted)

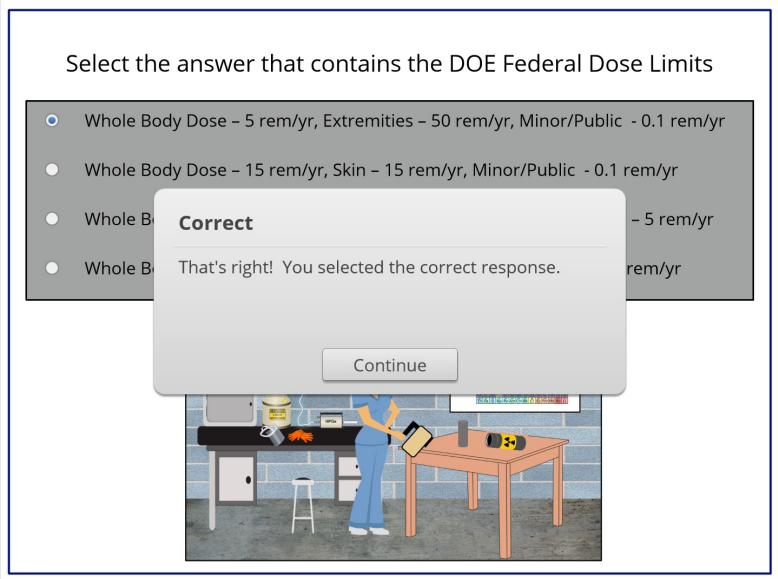


Correct	Choice
X	Whole Body Dose – 5 rem/yr, Extremities – 50 rem/yr, Minor/Public - 0.1 rem/yr
	Whole Body Dose – 15 rem/yr, Skin – 15 rem/yr, Minor/Public - 0.1 rem/yr
	Whole Body Dose – 5 rem/yr, Extremities – 50 rem/yr, Minor/Public – 5 rem/yr
	Whole Body Dose – 50 rem/yr, Skin – 50 rem/yr, Minor/Public – 0.5 rem/yr

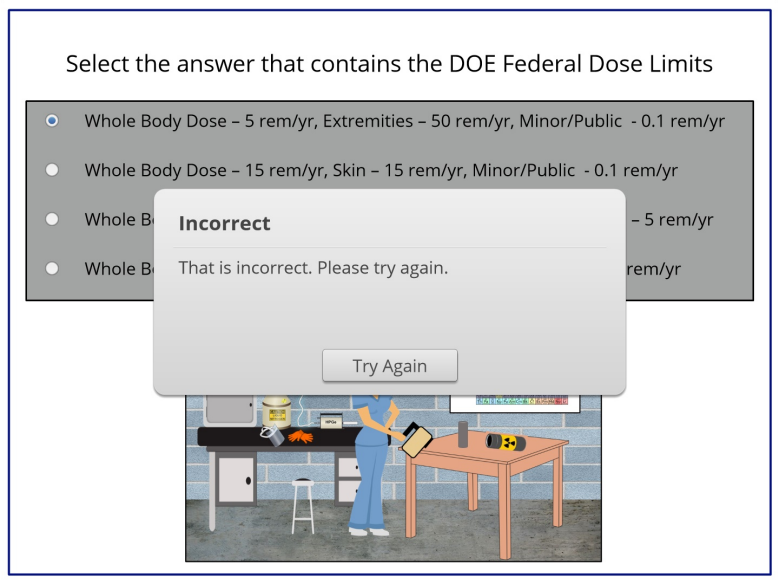
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

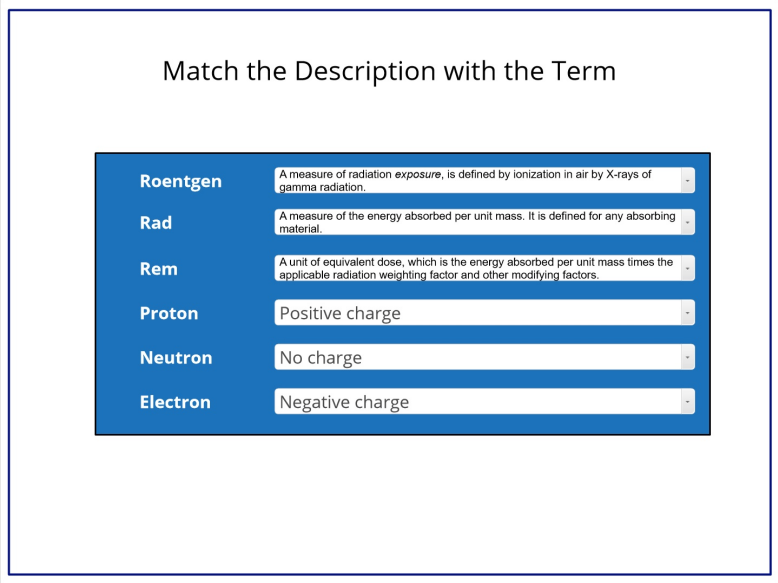


Try Again (Slide Layer)



5.13 Knowledge Check

(Matching Drop-down, 10 points, unlimited attempts permitted)

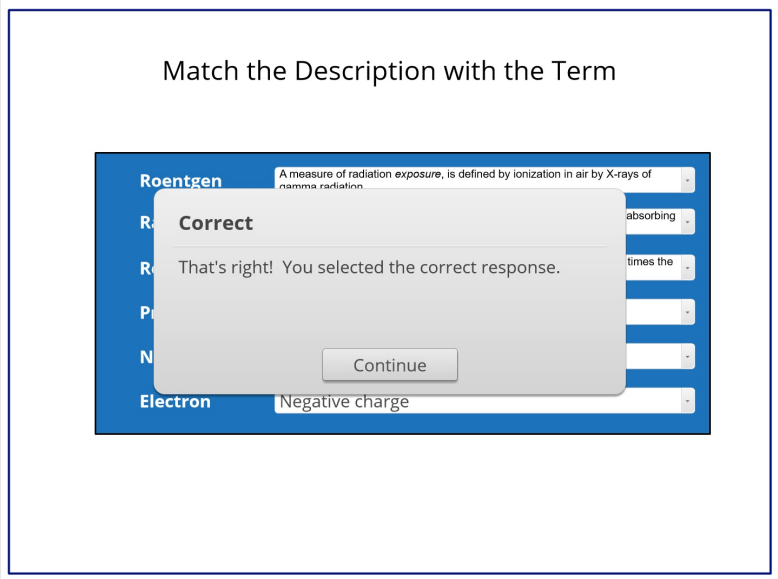


Correct	Choice
Roentgen	A measure of radiation exposure, is defined by ionization in air by X-rays of gamma radiation.
Rad	A measure of the energy absorbed per unit mass. It is defined for any absorbing material.
Rem	A unit of equivalent dose, which is the energy absorbed per unit mass times the applicable radiation weighting factor and other modifying factors.
Proton	Positive charge
Neutron	No charge
Electron	Negative charge

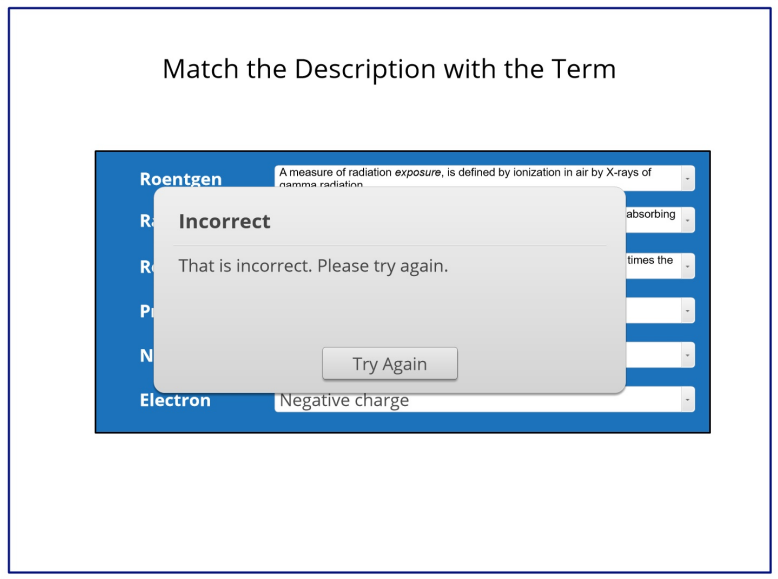
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

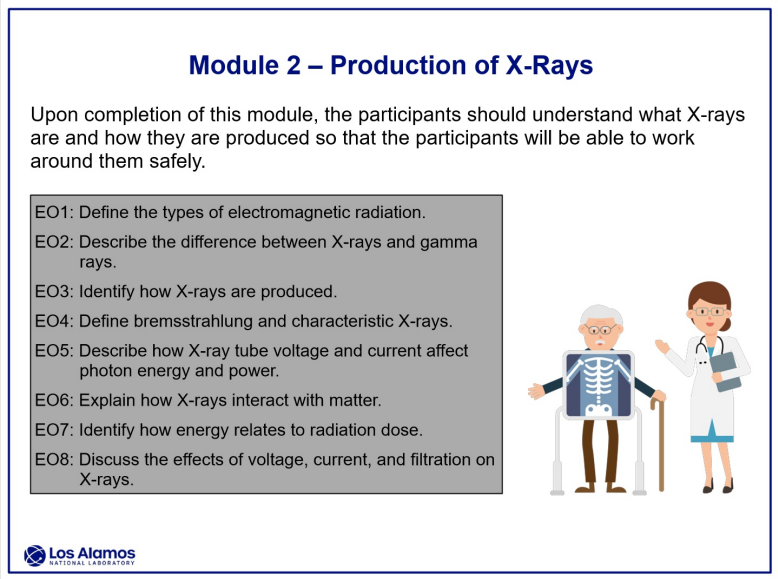


Try Again (Slide Layer)

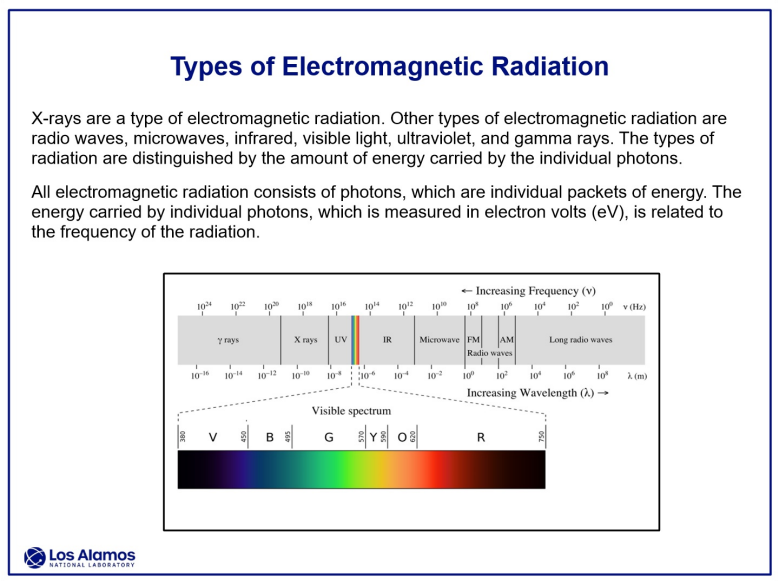


6. Module 2 - Production of X-Rays

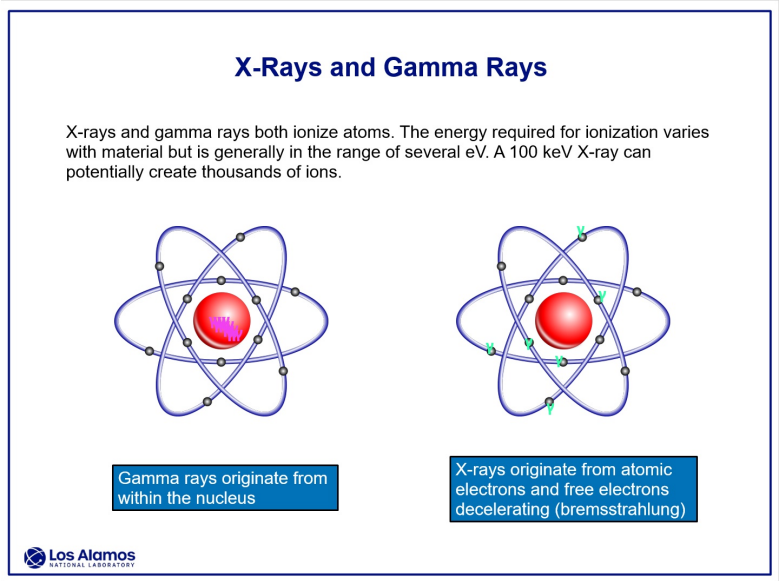
6.1 Module 2 Objectives



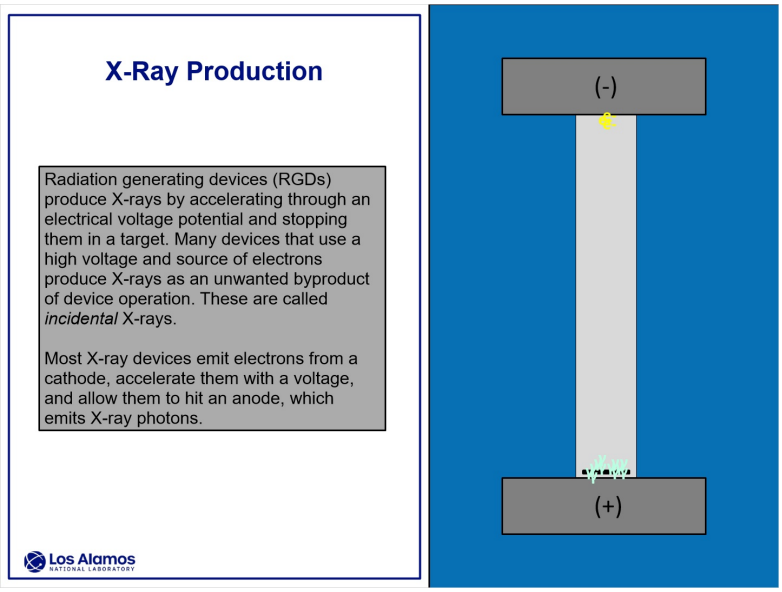
6.2 Types of Electromagnetic Radiation



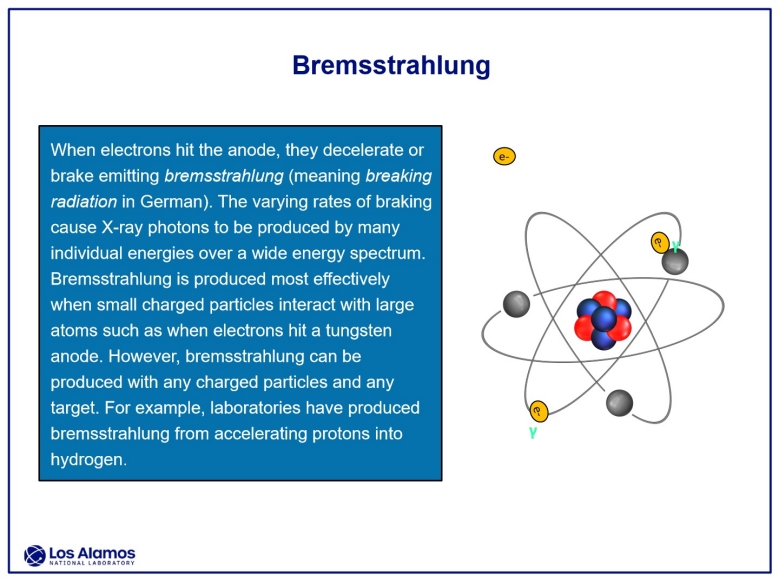
6.3 X-Rays and Gamma Rays



6.4 X-Ray Production

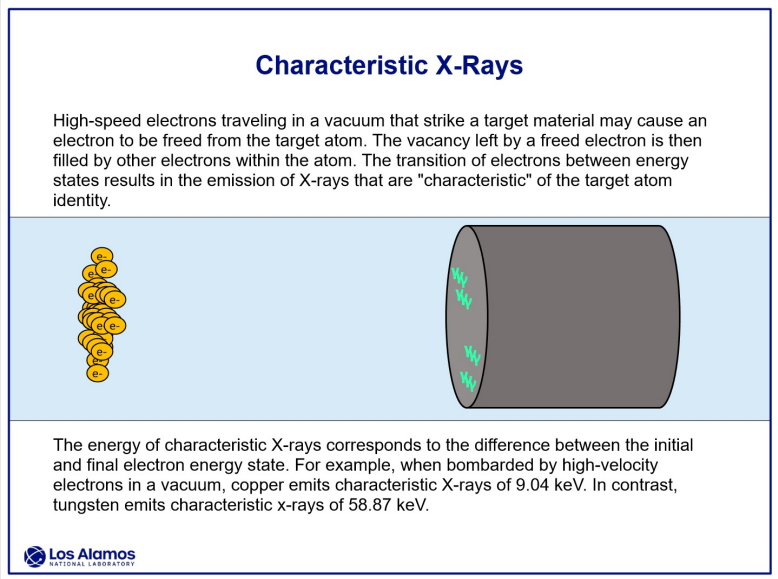


6.5 Bremsstrahlung



Notes:

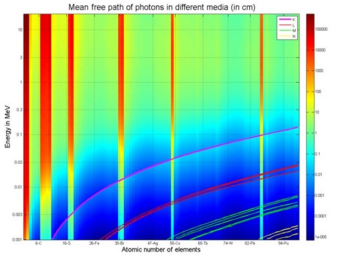
6.6 Characteristic X-Rays



Notes:

6.7 Photon Energy and Power

Effect of Voltage and Current on Photon Energy and Power



It is important to distinguish between the energy of individual photons in an X-ray beam and the total energy of all the photons in a beam, as well as the difference between the average power and peak power in a pulsed X-ray device.

Typically, the individual photon energy is given in electron volts (eV), whereas the power of a beam is given in watts (W). An individual 100 keV photon has more energy than an individual 10 keV photon. However, an X-ray beam consists of a spectrum of photon energies and the rate at which energy is delivered by a beam is determined by the number of photons of each energy.

The photon energy distribution may be varied by changing the voltage. The number of photons emitted may be varied by changing the current.

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6.8 Voltage and Current

Voltage and Current

Voltage

- The photon energy produced by an RGD depends on the voltage, which is measured in volts (V). A voltage of 10 kV will produce up to 10-keV X-ray photons.
- Most of the X-ray photons produced by a given maximum electron acceleration potential will be approximately 1/3 of the maximum electron potential. For example, a 120-kV-peak (kvp) diagnostic RGD produces X-ray photons with an average of 40 keV.
- Whenever voltage is on, a device can produce X-rays even if the currents is too low to read.

Current

- The total number of photons produced by an RGD depends on the current, which is measured in amperes, or amps (A).
- The current is controlled by increasing or decreasing the number of electrons emitted from the cathode.
- The higher the electron current, the more X-ray photons emitted from the anode. Many RGDs have meters to measure the X-ray current produced.

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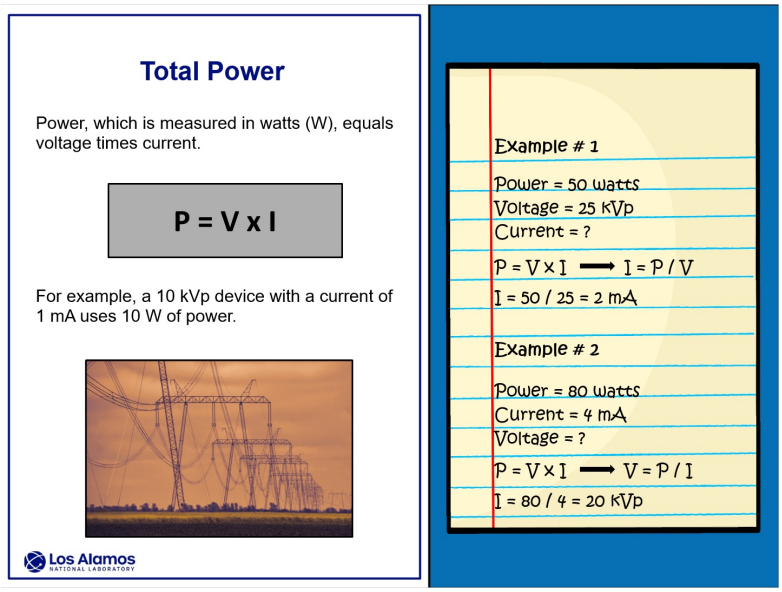
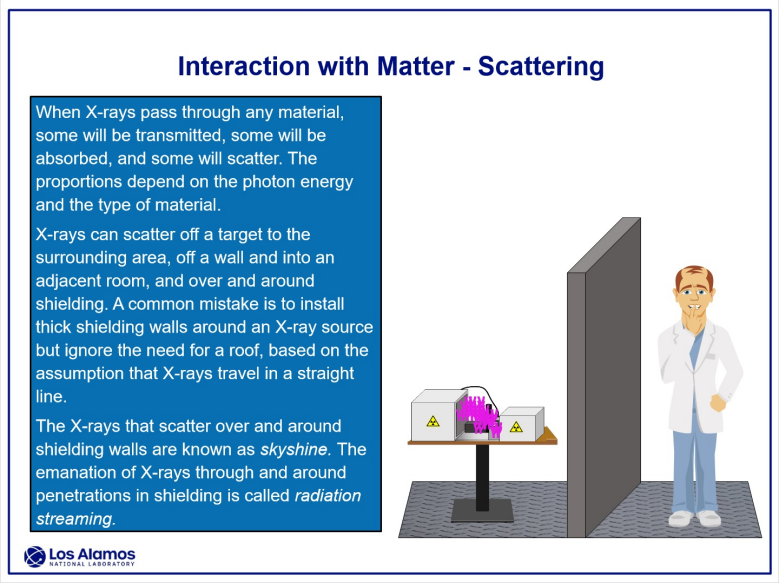
6.9 Total Power



6.10 Scattering



6.11 Implications of Power and X-Ray Productions

Implications of Power and X-Ray Productions

When high-speed electrons strike the anode target, most of their energy is converted to heat, but a portion is radiated away as X-rays. The electrical power of a circuit is given by:

P = V x I

The power developed in the anode of an X-ray tube can be calculated using this relationship. Consider a 150 kilovolt (kVp) machine, with a current of 50 milliamps.

P = [150,000 (V)][0.050 (I)] = 7,500 W

This is about the same heat load as would be found in the heating element of an electric stove. Power is delivered over a very short period of time, typically less than 1 second. More powerful X-ray machines use higher voltages and currents and may develop power as high as 50,000 W or more. Cooling the anode is a problem that must be addressed in the design of X-ray machines. Tungsten is used because of its high melting point, and copper is used because of its excellent thermal conductivity.

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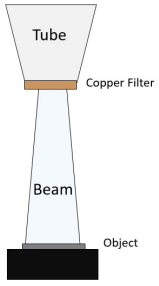
6.12 Filtration

Filtration

Low and high energy photons are sometimes referred to as soft and hard X-rays, respectively. Because hard X-rays are more penetrating, they are more desirable for radiography (producing a photograph of the interior of the body or apparatus). Soft X-rays are less useful for radiography because they are largely absorbed near the surface of the body being X-rayed. However, there are medical applications where the soft X-rays are useful.

- A filter, such as a few millimeters of aluminum, or copper may be used to harden the beam by absorbing most of the low-energy photons. The remaining photons are more penetrating and useful.
- In the X-ray analytical work, filters with energy selective absorption edges are not used to harden the beam, but to obtain a more monochromatic beam.
- By choosing the right element, it is possible to absorb a band of high-energy photons preferentially over an adjacent band of low energy photons.



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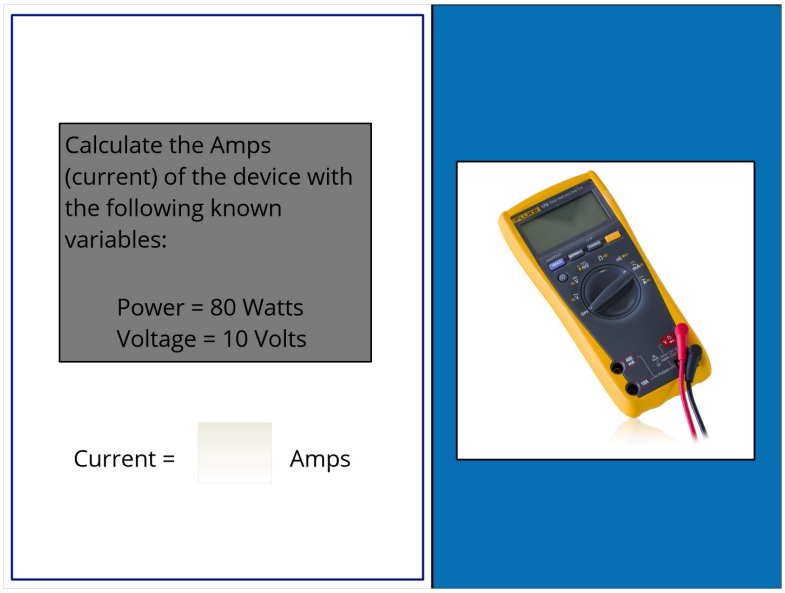
6.13 Knowledge Check

(Numeric, 10 points, unlimited attempts permitted)

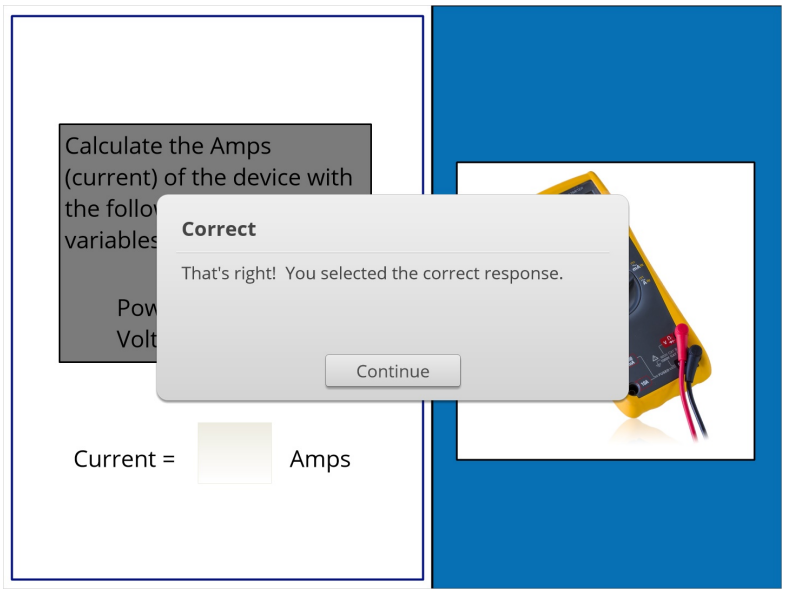


Acceptable numeric values	
Equal to	8

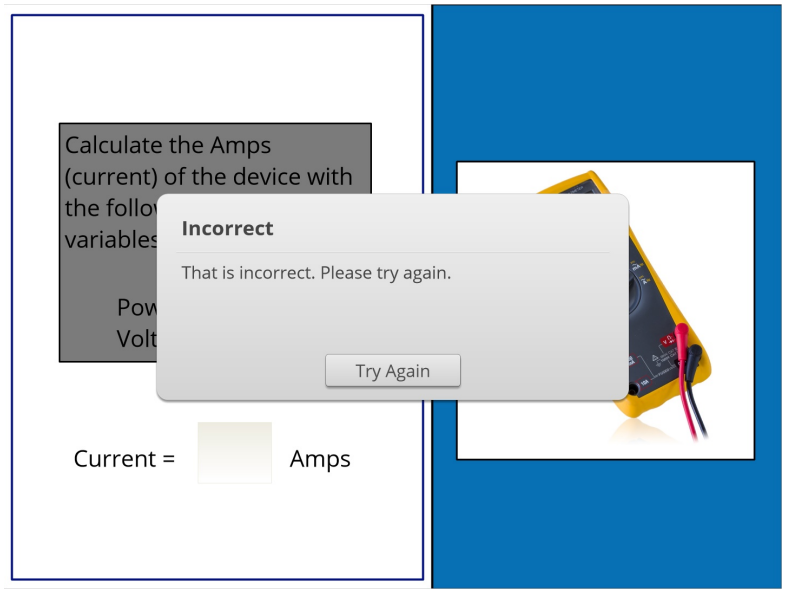
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

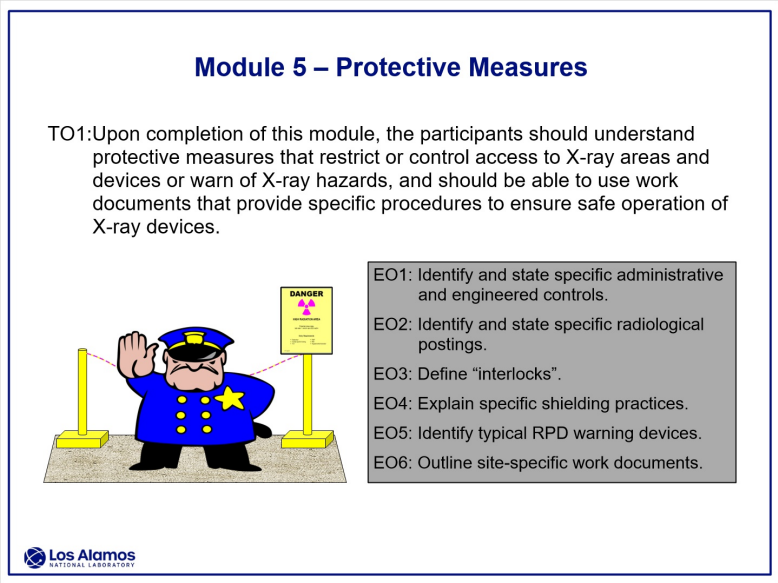


Try Again (Slide Layer)

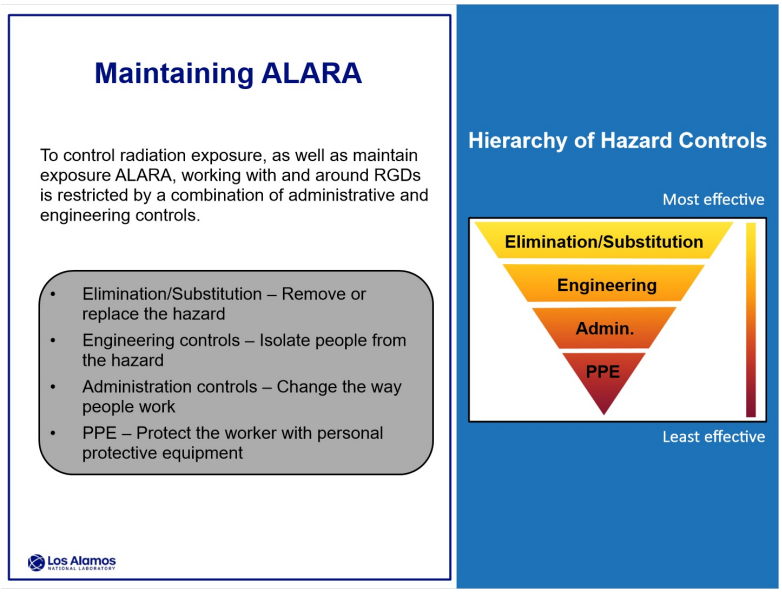


7. Module 5 - Protective Measures

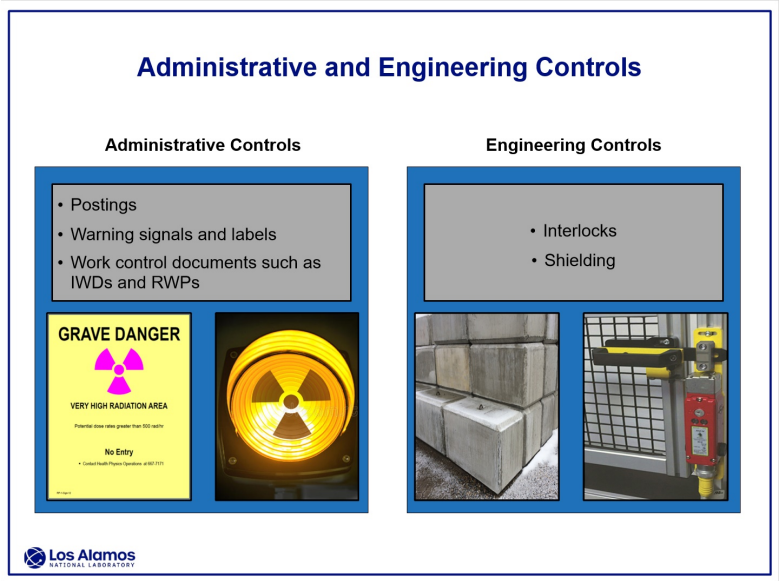
7.1 Module 5 Objectives



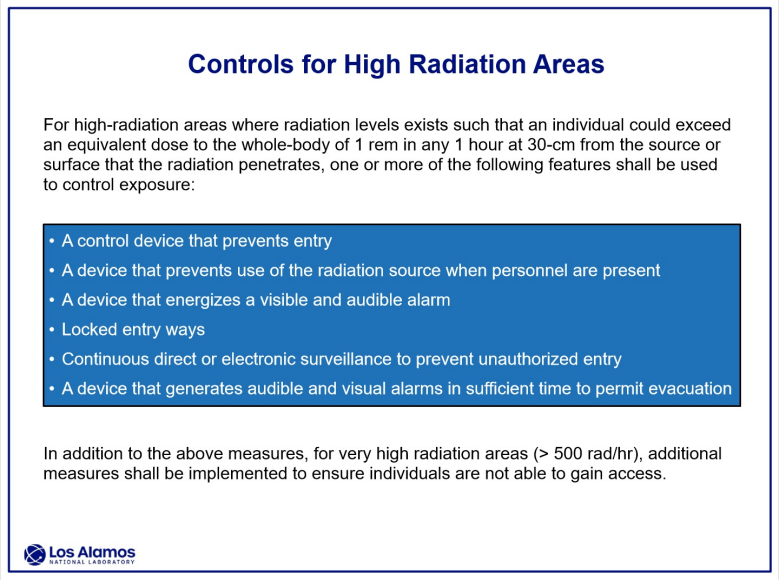
7.2 Maintaining ALARA



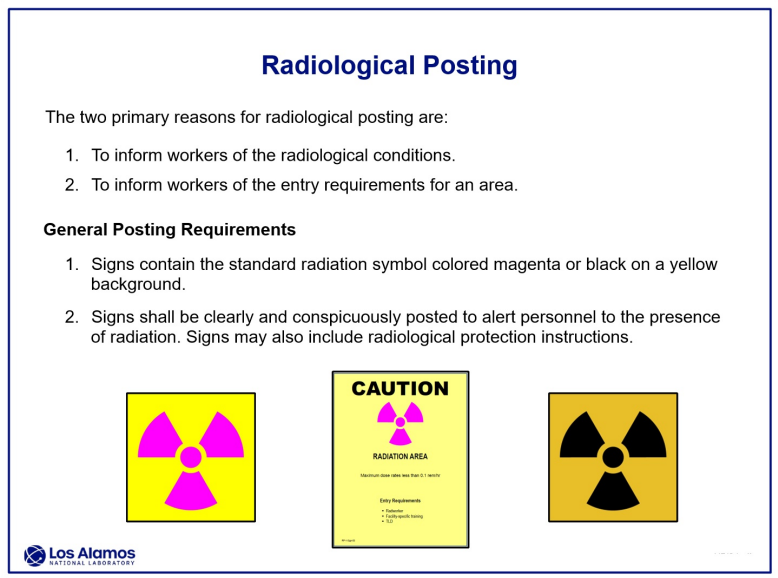
7.3 Administrative and Engineering Controls



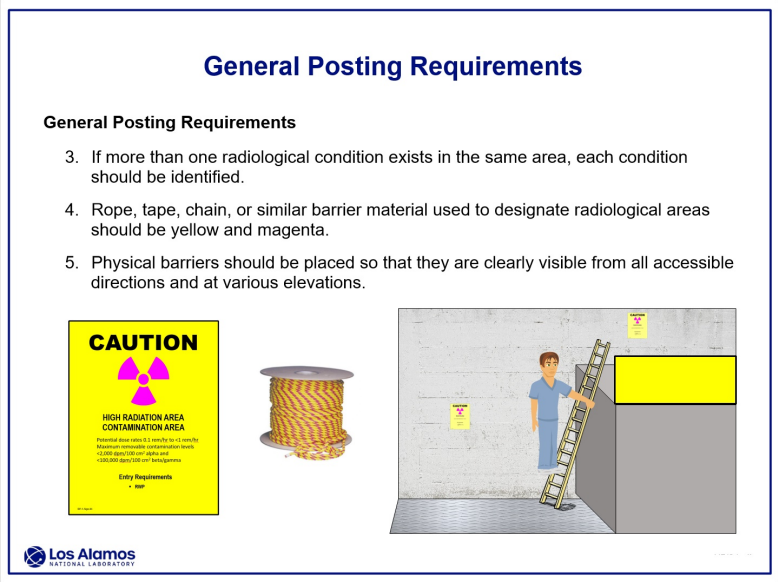
7.4 Controls for HRA



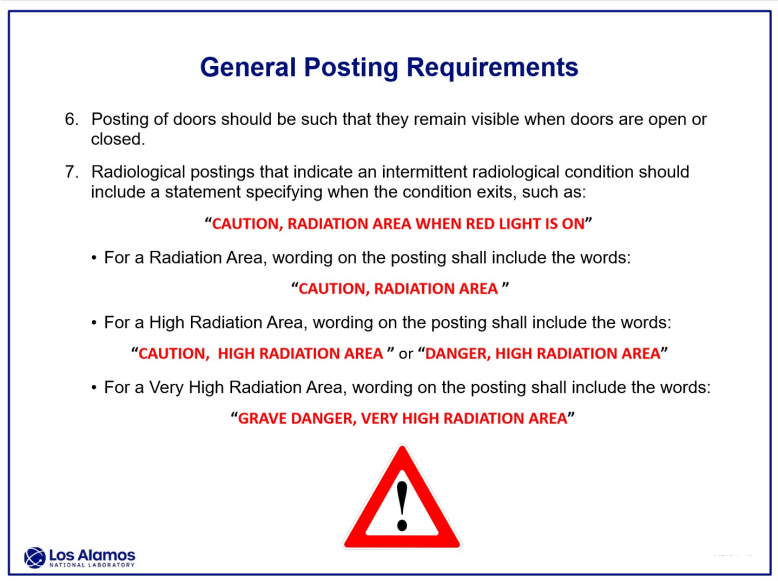
7.5 Radiological Posting



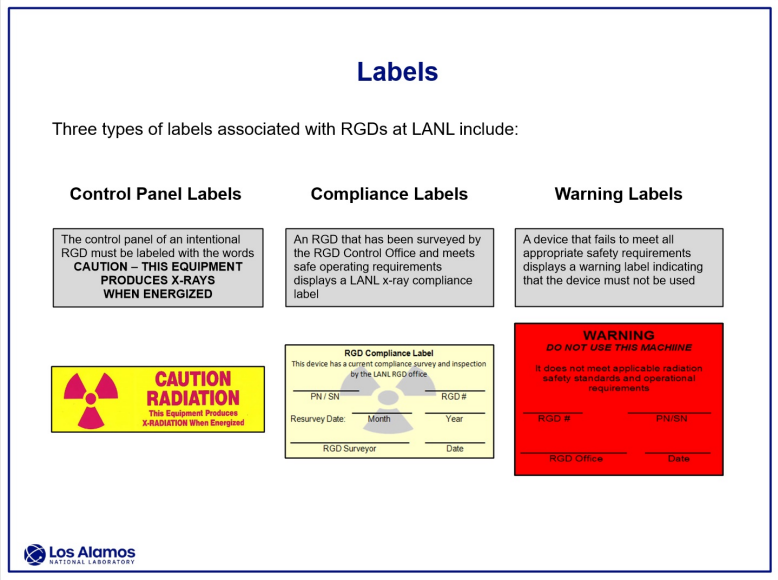
7.6 General Posting Requirements



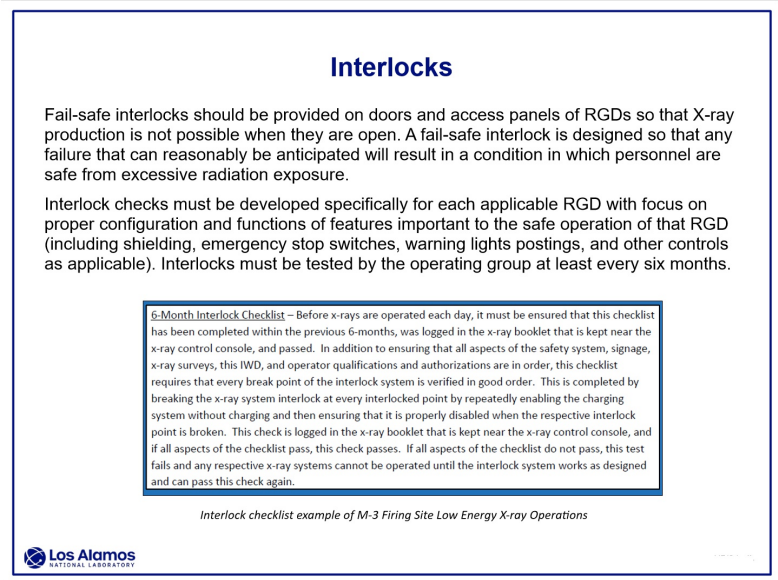
7.7 General Posting Requirements



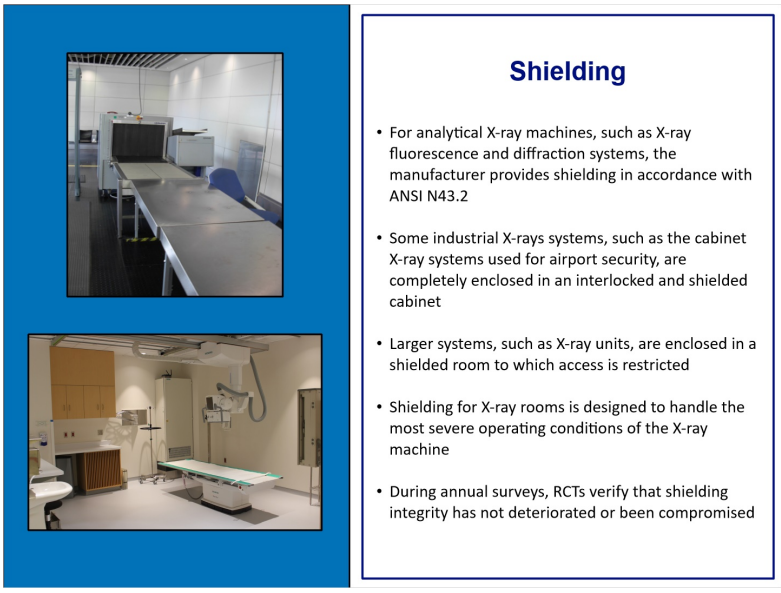
7.8 Labels



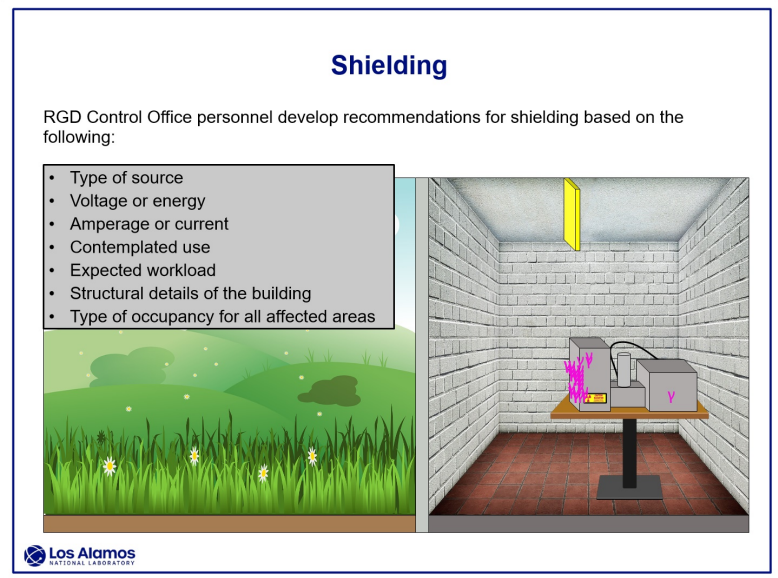
7.9 Interlocks



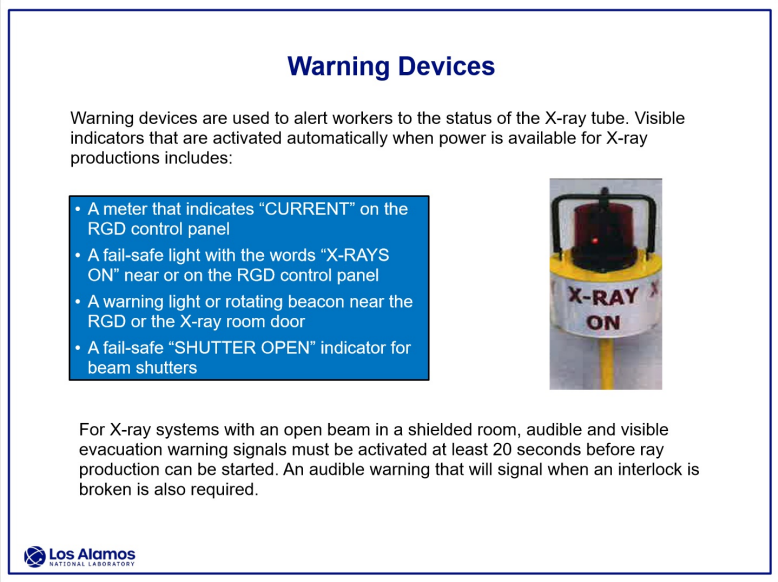
7.10 Shielding



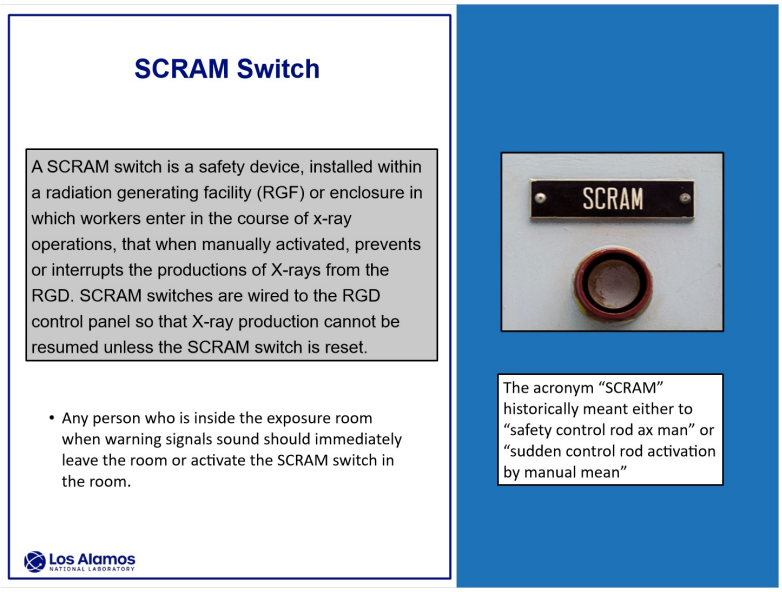
7.11 Shielding



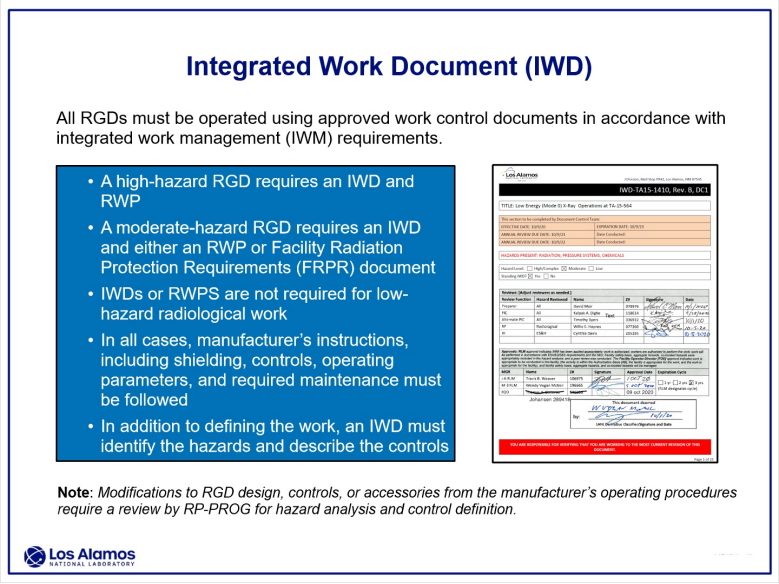
7.12 Warning Devices



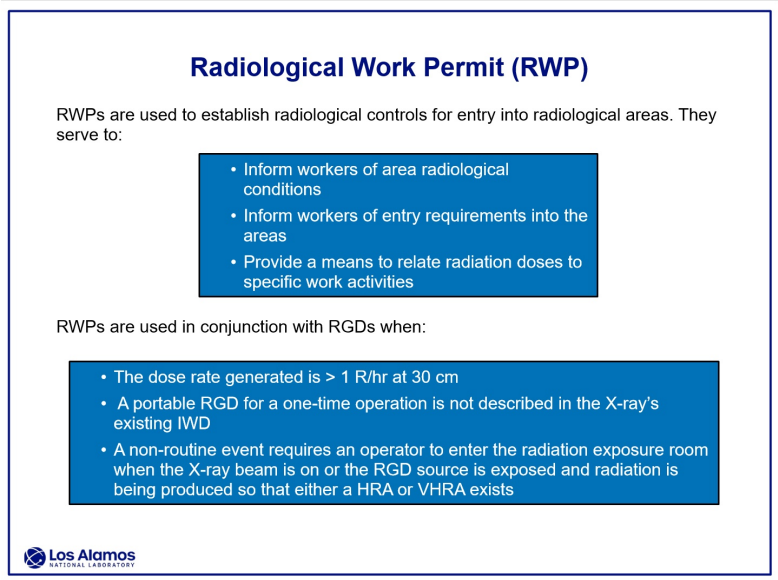
7.13 SCRAM Switch



7.14 Integrated Work Document

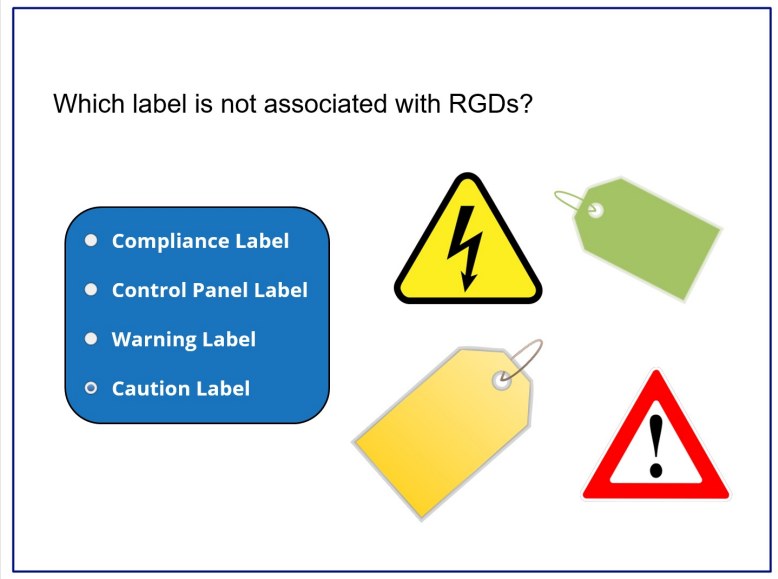


7.15 Radiological Work Permit



7.16 Knowledge Check

(Multiple Choice, 10 points, unlimited attempts permitted)



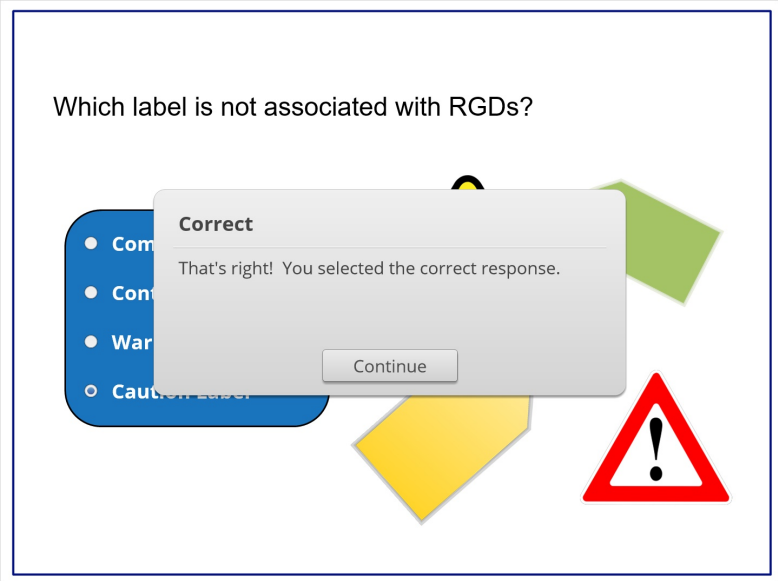
Correct	Choice
	Compliance Label

	Control Panel Label
	Warning Label
X	Caution Label

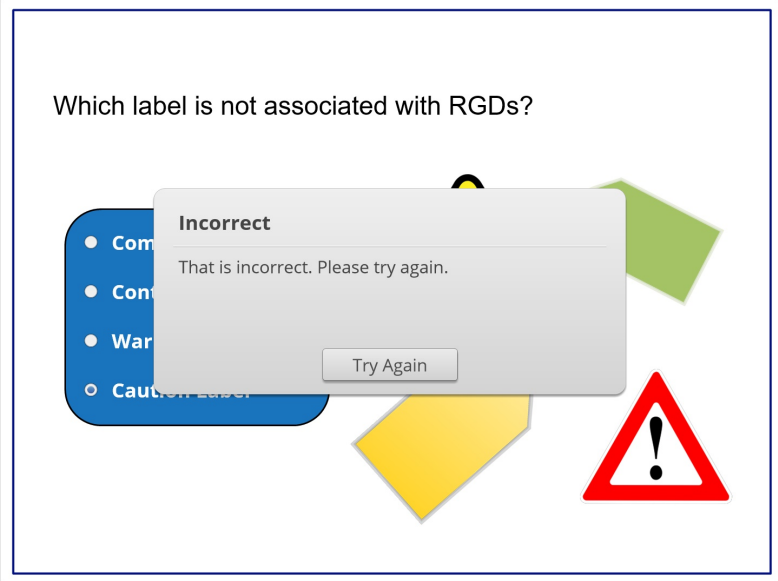
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

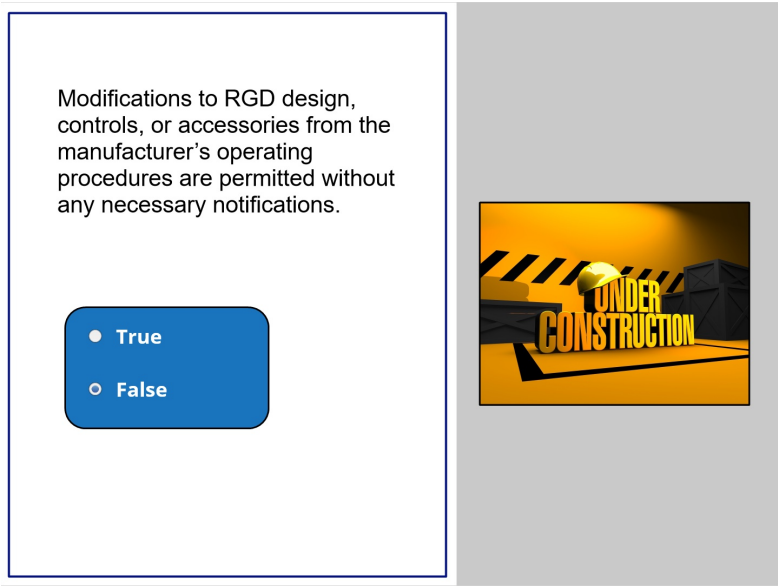


Try Again (Slide Layer)



7.17 Modifications to RGD design, controls, or accessories from the manufacturer's operating procedures are permitted without any necessary notifications.

(True/False, 10 points, unlimited attempts permitted)

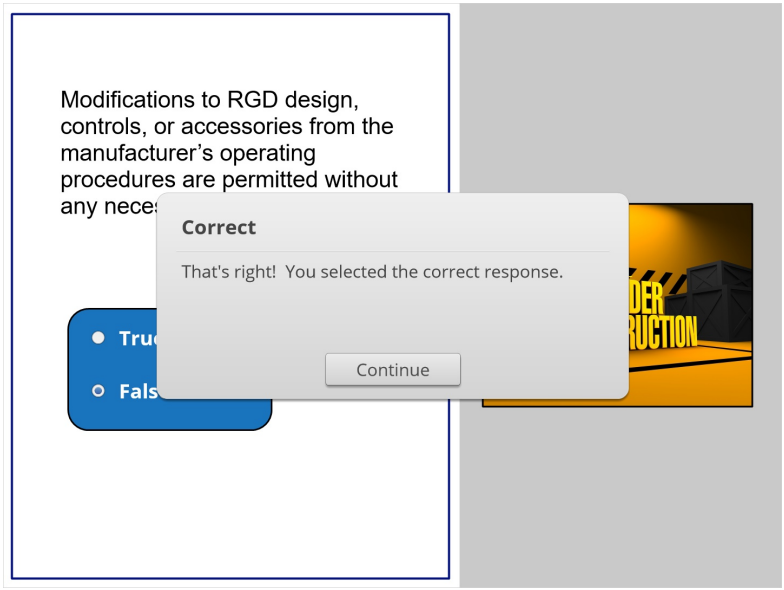


Correct	Choice
	True
X	False

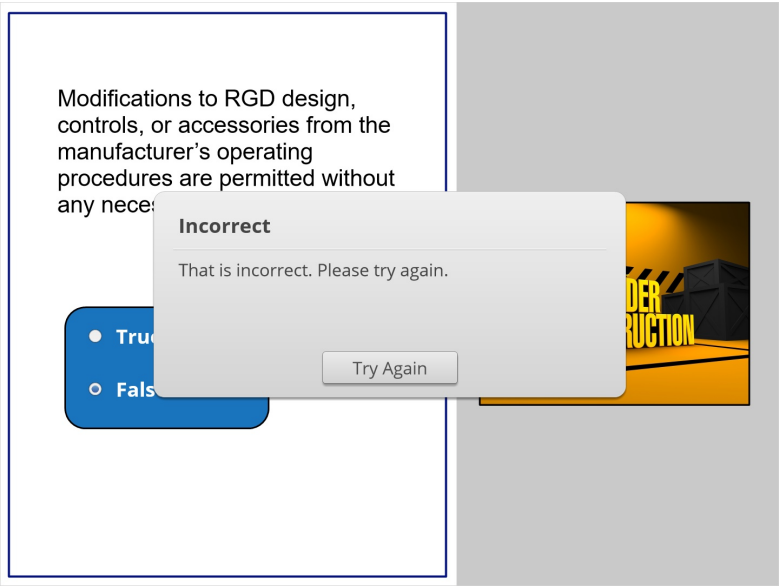
Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

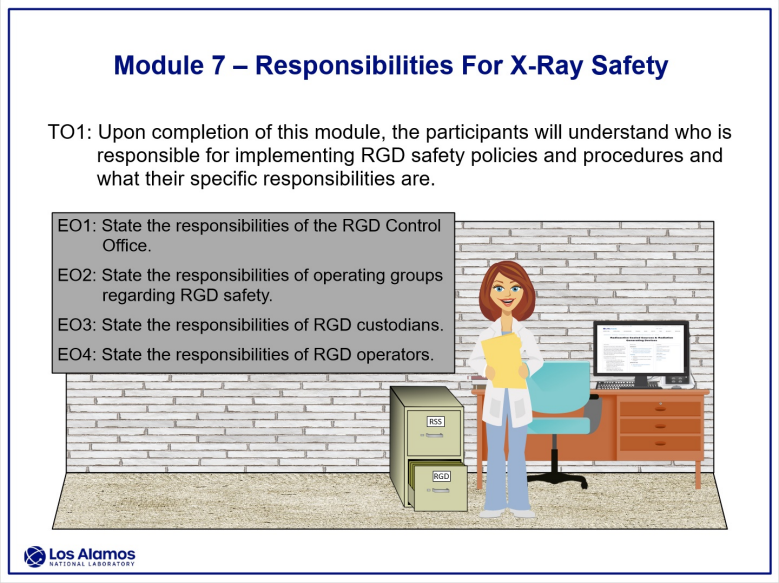


Try Again (Slide Layer)

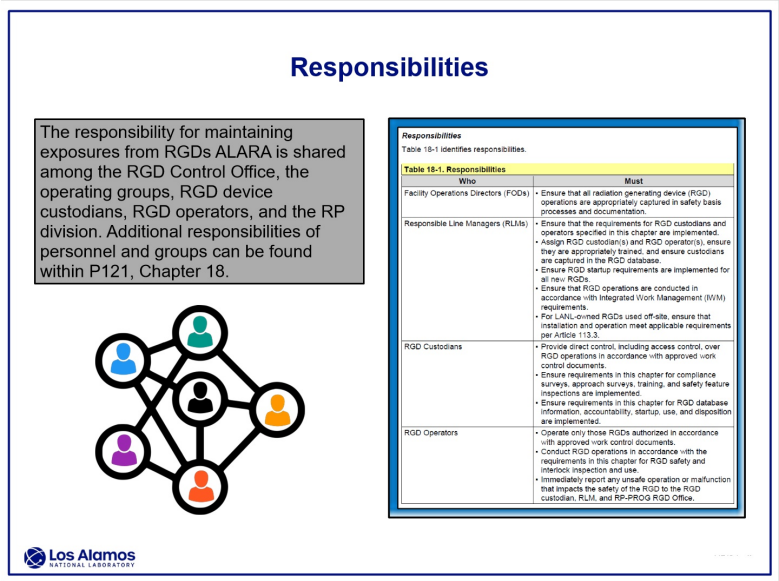


8. Module 7 - Responsibilities For X-Ray Safety

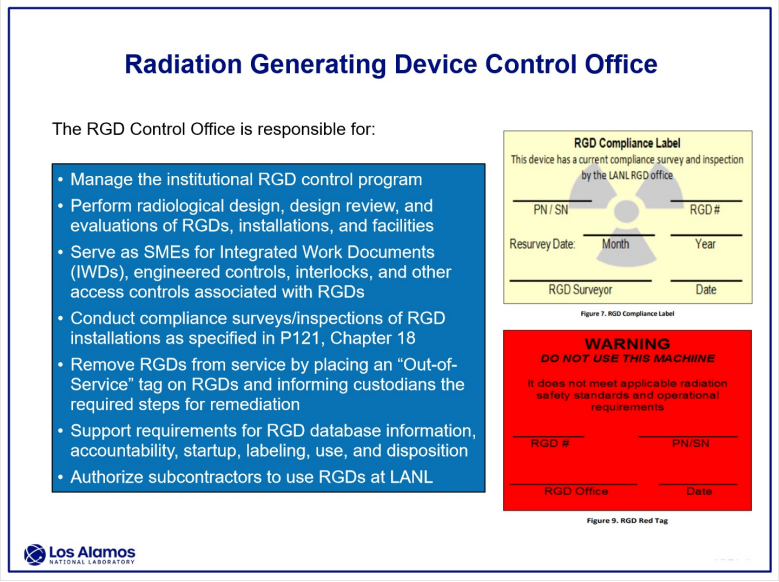
8.1 Module 7 Objectives



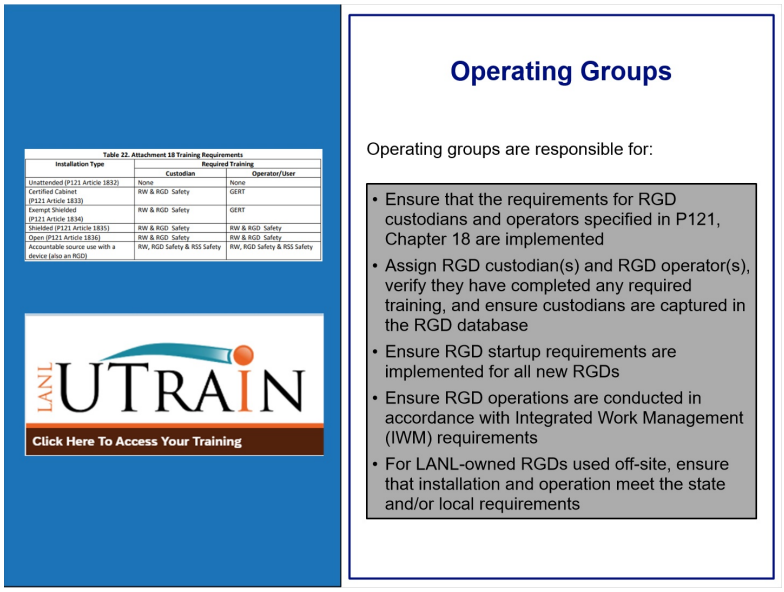
8.2 Responsibilities



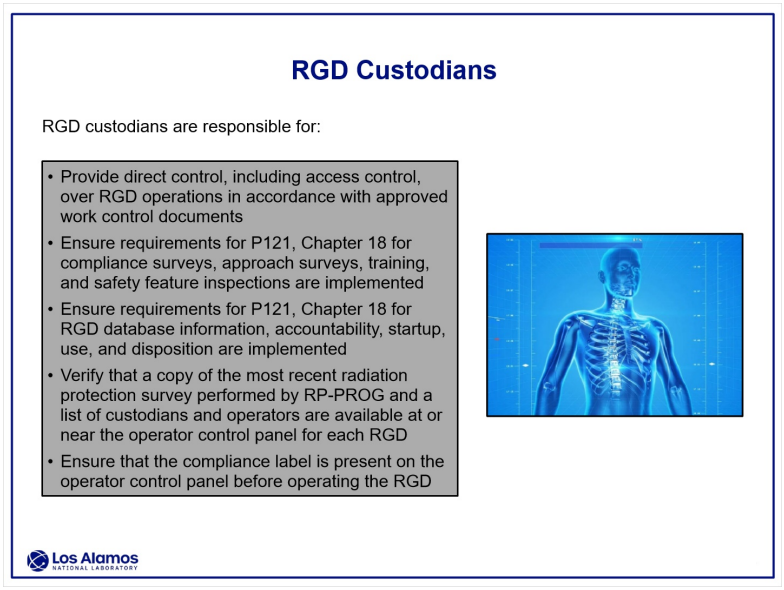
8.3 RGD Control Office



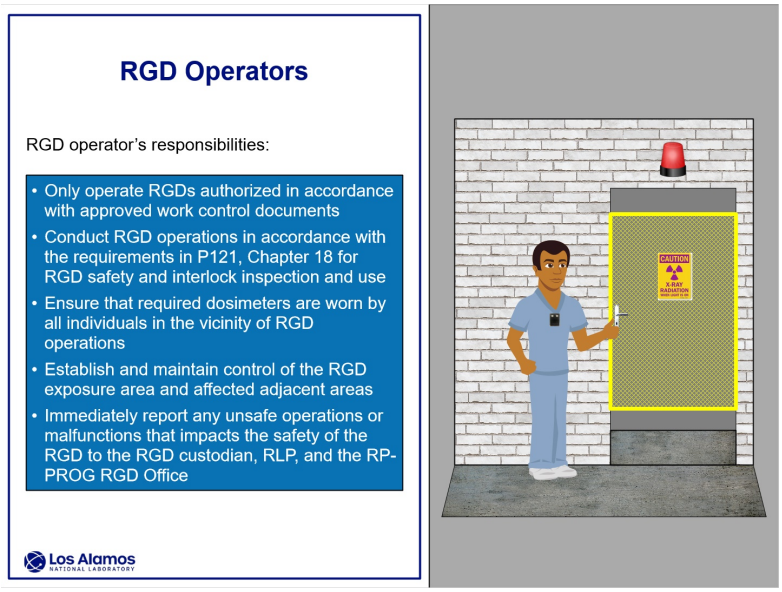
8.4 Operating Groups



8.5 RGD Custodians

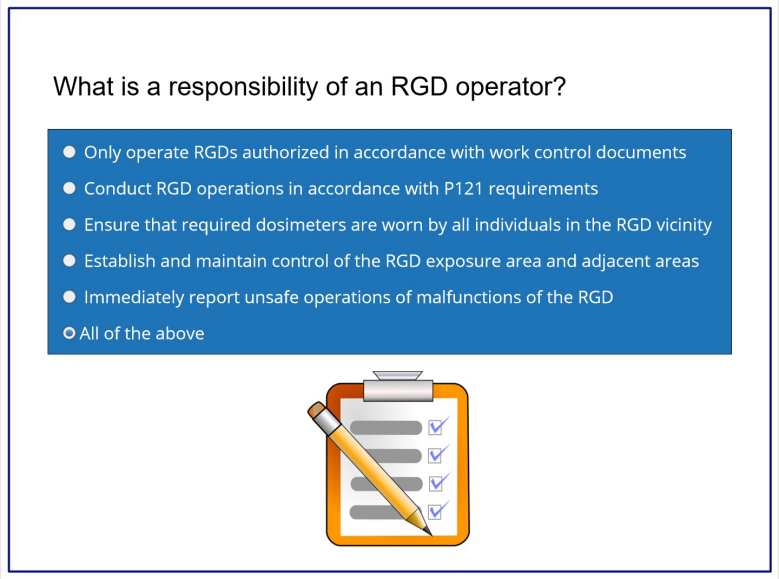


8.6 RGD Operators



8.7 Knowledge Check

(Multiple Choice, 10 points, unlimited attempts permitted)



Correct	Choice
	Only operate RGDs authorized in accordance with work control documents

	Conduct RGD operations in accordance with P121 requirements
	Ensure that required dosimeters are worn by all individuals in the RGD vicinity
	Establish and maintain control of the RGD exposure area and adjacent areas
	Immediately report unsafe operations of malfunctions of the RGD
X	All of the above

Feedback when correct:

That's right! You selected the correct response.

Correct (Slide Layer)

Try Again (Slide Layer)